NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
INVENTIONS AND CONTRIBUTIONS BOARD
SPACE ACT AWARD APPLICATION

BACKGROUND:

<u>THE NASA SPACE ACT MONETARY AWARDS PROGRAM FOR SIGNIFICANT SCIENTIFIC AND TECHNICAL CONTRIBUTIONS</u>

The objectives of this program are to provide official recognition of, and to grant equitable monetary awards for those inventions and other scientific and technical contributions that have helped to achieve NASA's aeronautical, commercialization, and space goals; and to stimulate and encourage the creation and reporting of similar contributions in the future. To accomplish these objectives, the Inventions and Contributions Board is authorized to recommend the granting of monetary awards in amounts up to $100,000 in accordance with the provisions of the National Aeronautics and Space Act of 1958, and to grant monetary awards in amounts up to $10,000 in accordance with the provisions of the Government Employees Incentive Awards Act of 1954. Space Act awards can be made to any person with no restriction as to employer, and in accordance with the regulations as specified in the Federal Register Vol. 55, No. 5, (14 CFR Part 1240). Awards made under the authority of the Incentive Awards Act can be made to U.S. Government employees only.

GUIDELINES:

In determining the merits of an invention or a contribution, the Board depends primarily on the information provided by the contributor(s)/technical evaluator in the Space Act Award Application. Furthermore, the Board recognizes that NASA technical personnel are the best sources of reliable information concerning contributions made by employees of NASA or by employees of NASA's contractors whose activities are under their cognizance. For this contribution, it is appropriate for the contributor(s)/ technical evaluator to supply the information that the Board requires in order to make a recommendation that is equitable to both the contributor(s) and NASA. We are therefore asking you to assist the Board by completing, accurately and thoroughly, the application which follows these explanatory remarks. For your convenience we suggest that you familiarize yourself with the contents of the application by reading it completely before answering the questions. Please provide all pertinent facts, specific details, explanations, and opinions regarding seven important factors that characterize the contribution. These factors are: (1) Description, (2) Significance, (3) Stage of Development, (4) Use, (5) Creativity, (6) Recognition and (7) Tangible Value. The Board welcomes any additional information that you believe will contribute to the completeness of its deliberations. If you find it necessary to modify or expand the format of the application in order to provide such extra information, please do so.

REQUIRED DOCUMENTATION AND AWARDS LIAISON OFFICE RESPONSIBILITY:

Please be thorough and candid with your evaluation. Each section must be filled in, and where appropriate, signed by the evaluators. **In no case should the evaluator be identified as a contributor**. The full legal name, employer’s name and percentage contribution for each contributor is mandatory and at least one NASA official must sign in Section II to attest to NASA's sponsorship, adoption, support or use of the contribution. If any supplementary materials are provided; e.g., additional sheets, technical papers, engineering drawings, videotape, audio cassettes, photographs, computer diskettes, etc., each must be marked and identified by the NASA Case Number and be converted to electronic format. The names and contact information for individuals familiar with the contribution would be helpful for evaluation. The Awards Liaison Officer of the NASA Center where the contribution is supported is responsible for accepting the application and subsequent submission to the Board. Please ensure that the contributors have signed a Privacy Act statement such as that forwarded to the Awards Offices by the ICB on May 13, 1992. All contributions should be officially reported to NASA by submission of Form 1679 Disclosure of Invention and New Technology (Including Software). In no case may a software innovation be reported on this form unless the software has been officially released by NASA to qualified users and reported to the ICB.

The Board sincerely appreciates the time and effort you will devote to the completion of the Space Act Award Application. We pledge to take prompt action to review and process your application. It is our intent to expeditiously reward excellence.

NASA FORM 1329	Inventions and Contributions Board *Space Act Award Application*	NASA Case Number: ARC-14785-1	Date: **April 14, 2004**
SECTION I *SPACE ACT AWARD APPLICATION*			
TITLE **The Collaborative Information Portal** *Ubiquitous Computing through Innovation*			

1. DESCRIPTION.

a. *Briefly describe the contribution. In addition, if peer-reviewed publications by contributors have been accepted on this topic in refereed journals or for refereed conference papers, please attach a copy with this form as a supplement.*

NASA's Mars Exploration Rovers Mission (MER) has been phenomenally successful. Both rovers, Spirit and Opportunity, continue to send billions of bytes of data and images from Mars to Earth, and they are making discoveries that will keep scientists busy for years to come.

But the mission is not just about the rovers. On Earth, two teams of people manage the mission, control the rovers, and analyze the downloaded data. The Collaborative Information Portal (CIP) is Class A, Mission–Critical software that plays a major role in ensuring that everyone works well together efficiently and effectively. CIP users can view current event and staffing schedules, download data and image files generated by the rovers, receive broadcast messages, and get accurate times in various Earth and Mars time zones. People rely on it throughout all stages of daily mission operations, whether they were working inside mission control or in the science areas at JPL or throughout the world.

As CIP's developers, we overcame major challenges:

- *CIP is task oriented and user oriented.* CIP performs many tasks that enable its users to do their jobs. It also must be intuitively easy to use. We continually solicited and responded to user feedback.
- *CIP is scalable.* It accommodates ever-increasing numbers of users and user requests without significant performance degradation.
- *CIP is extensible.* Requirements and specifications constantly evolved. The mission added new tasks, and it removed obsolete tasks. The CIP architecture makes adding and removing code modules straightforward.
- *CIP is reliable.* A mission–critical application in use everywhere by everyone must minimize downtime.
- *CIP is secure.* It complies with JPL's security constraints to protect the downloaded images and data.
- *CIP is adjustable.* Day–to–day operational parameters often change during the mission, such as the current value in seconds of one-way light time from Earth to Mars. CIP adjusts to these changes while continuing to run.
- *CIP is flexible.* It supports multiple computing platforms and interaction models.

CIP has achieved *ubiquitous computing* — everyone uses CIP everywhere — because we were highly innovative. Everyone uses CIP because of our user–oriented innovations, which we describe below. Everyone can use CIP everywhere because of our architectural innovations, which we describe for Question 1.c.

"Everyone uses CIP" — User–oriented innovations

CIP successfully serves two distinct classes of users. Mission managers and engineers working inside mission control at the Jet Propulsion Laboratory (JPL) are responsible for controlling and communicating with the rovers during daily operations. Mission scientists and researchers working at JPL and worldwide plan each rover's operations, and they analyze the data and images downloaded from the rovers. People are organized into two teams, one per rover, although often people move from one team to the other. They all work on Mars time, and each person can have different roles at different times. While CIP has crosscutting functionality that makes it useful for both classes of users, its user–oriented innovations make people *want* to use it.

Figure 1.a-1 shows a screen shot of the CIP client application.

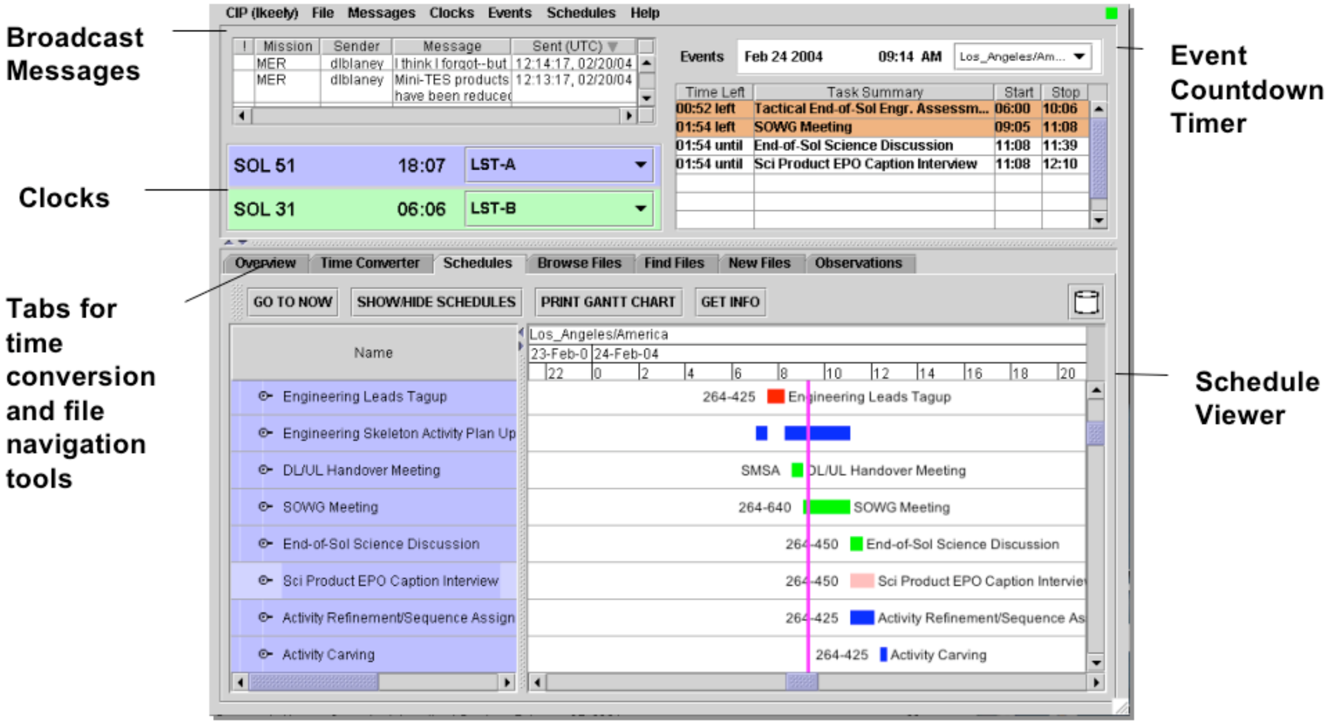


Figure 1.a-1: The CIP client application

Schedule Viewer

Mission personnel live by the staff and event schedules that CIP displays, especially if they work on Mars time. They rely upon CIP to let them know when events will occur, who is working when and where, and what roles they need to fill that day. The schedules are especially useful in helping people adjust to Mars time, since each Martian day (a "sol") is about 40 minutes longer than an Earth day. Because schedules are so important and highly visible, we incorporated many innovations into schedule viewing and creating.

Martian timescales. The Schedule Viewing tool allows users to display multiple timescales, including Mars Local Solar Time for each rover: LST-A for rover Spirit and LST-B for rover Opportunity. At run time, the user can choose one or more Martian and terrestrial timescales. See Figure 1.a-2

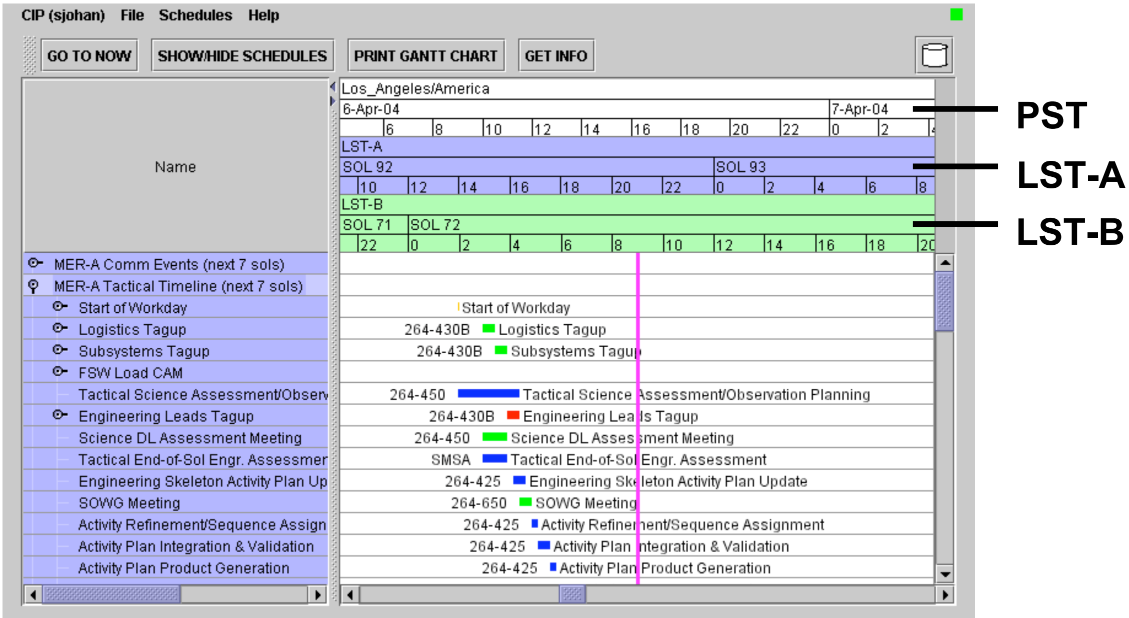


Figure 1.a-2: The Schedule Viewer with multiple schedule timescales, including Martian timescales

Adaptive timescales. The user specifies the amount of time to display, such as one day. Based on that selection and the current width of the application window, CIP selects the day/sol and hour time units and displays non–overlapping tick marks and labels. CIP automatically reselects the time units each time the user resizes the window or switches between tactical and strategic schedule views. See Figure 1.a-3.

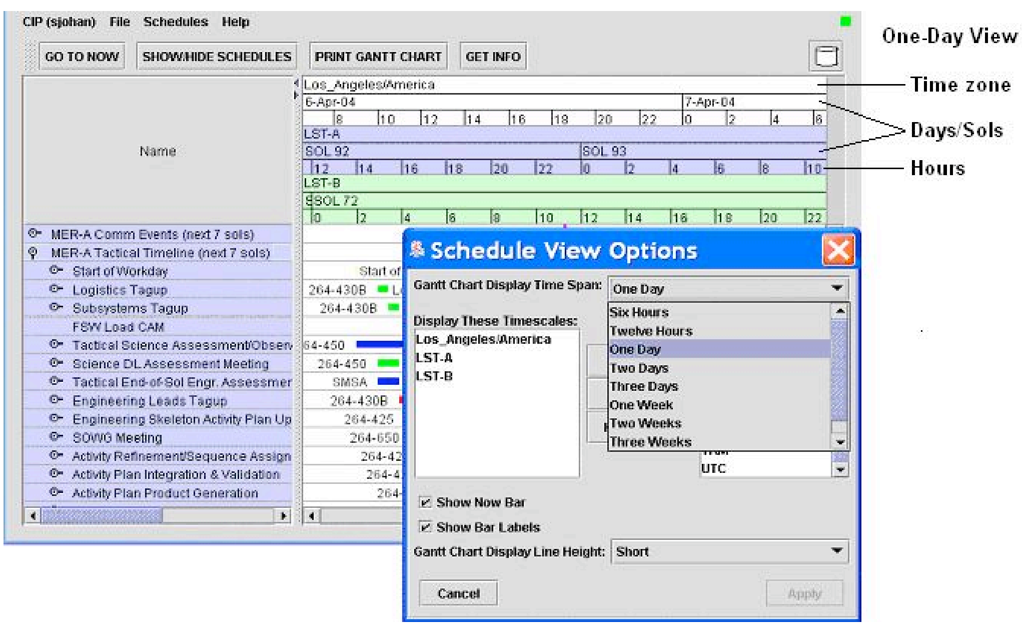


Figure 1.a-3: Selection of schedule time units

Now bar and time scrolling. The vertical magenta now bar indicates the current time (see Figure 1.a-2). Normally, the now bar remains fixed in the middle of the screen, and schedule events automatically move underneath as time passes. However, if the user scrolls the schedule horizontally with the scroll bar, the now bar automatically moves at the top of each minute and the events stay fixed. The Schedule Viewing tool keeps up with rendering the event bars and labels while the user scrolls.

Schedule coalescing. CIP can coalesce schedules created by different tools into a single unified schedule. We defined a schedule input file specification to which the output of each schedule creation tool must conform. Certain CIP users have the authority to upload schedule data into the schedule database. Whenever a user queries the database with a specific time interval, coalescing merges schedule data into a single unified schedule. See Figure 1.a-4.

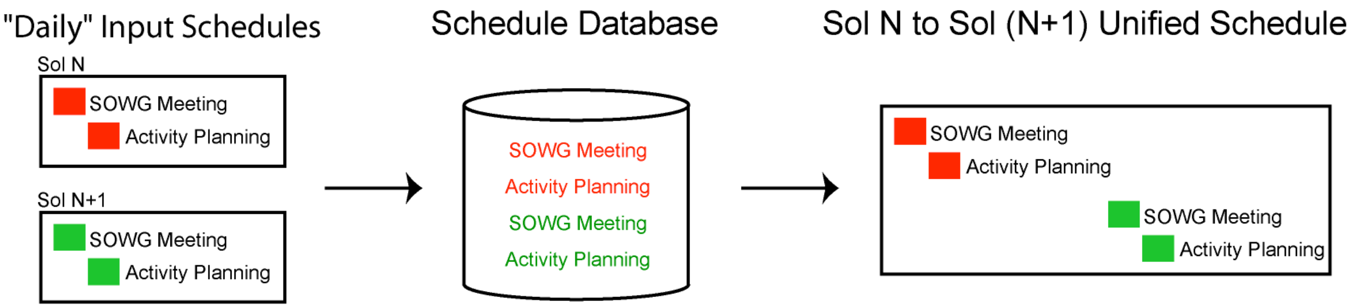


Figure 1.a-4: Schedule coalescing

Schedule correlation. Users can also correlate scheduled activities across time. CIP can automatically group together schedule activities based on their properties. For example, the Schedule Viewer can group together similar events, such as the daily SOWG meetings. See Figure 1.a-5.

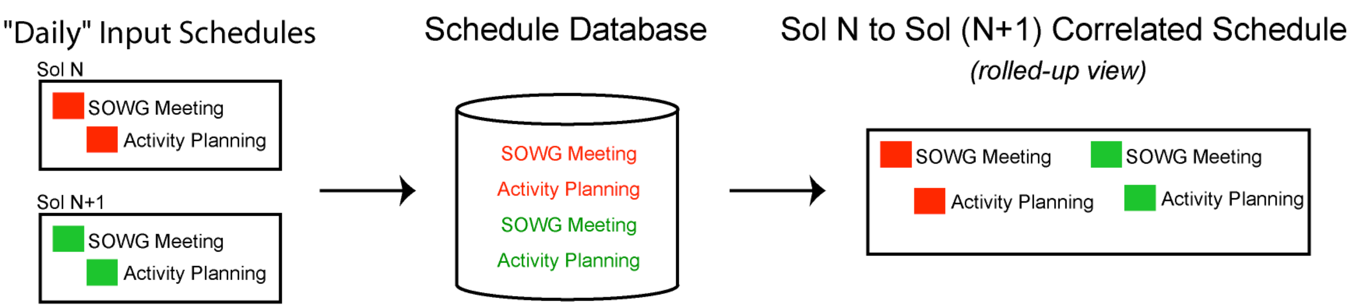


Figure 1.a-5: Schedule correlation

My Schedules. Each user constructs a personal set of schedules, and the user can choose whether to display each schedule. See Figure 1.a-6.

Figure 1.a-6: A user's personal set of schedules

Schedule Wizard. CIP supports both "canned" schedules and custom schedules. The Schedule Wizard creates custom schedules, which steps users through the process of building schedule queries. We collaborated with the Ames Applied HCI group to design this wizard. At each step, the options that the wizard displays depend on the contents of the schedule database. It has a navigation map that shows at which step a user is in the process and the options chosen in the previous steps. See Figure 1.a-7.

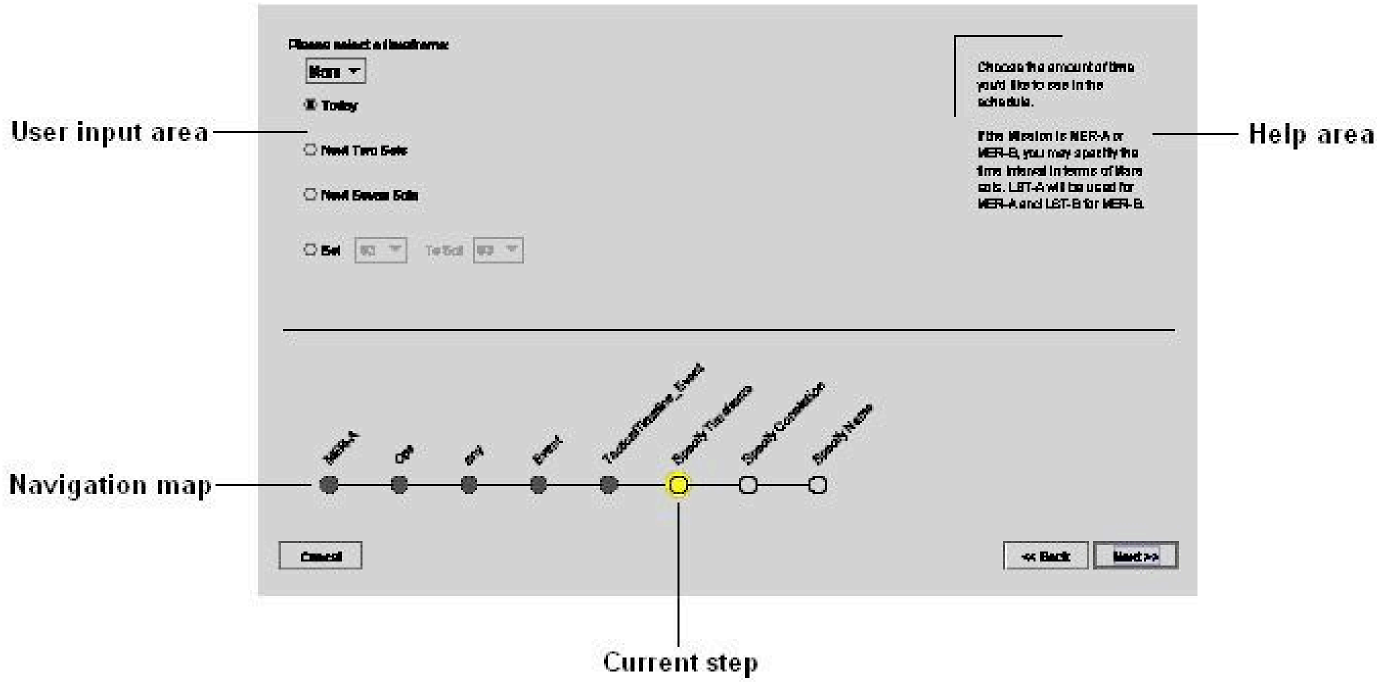


Figure 1.a-7: Wizard for building complex schedule queries

Absolute or symbolic retrieval time. When they make a schedule query, users can use absolute time in Earth or Martian time zones, such as "Sol 1 – Sol 2", or they can use symbolic time such as "today". Symbolic time allows a user to reuse a query every day, since the symbol is resolved at retrieval time.

Data Navigation

NASA scientists and researchers at JPL and worldwide rely on CIP to access and display the data and images downloaded by the rovers. CIP transports this information securely through the JPL firewalls and over the Internet. Scientists and researchers use CIP on workstations and laptops at JPL or in their offices or homes anywhere else in the world. We made several key innovations for data navigation.

Multiple viewing modes. Users can view the data and images organized as directories and files, or as "data products" organized by rover, sol, and instrument. See Figure 1.a-8.

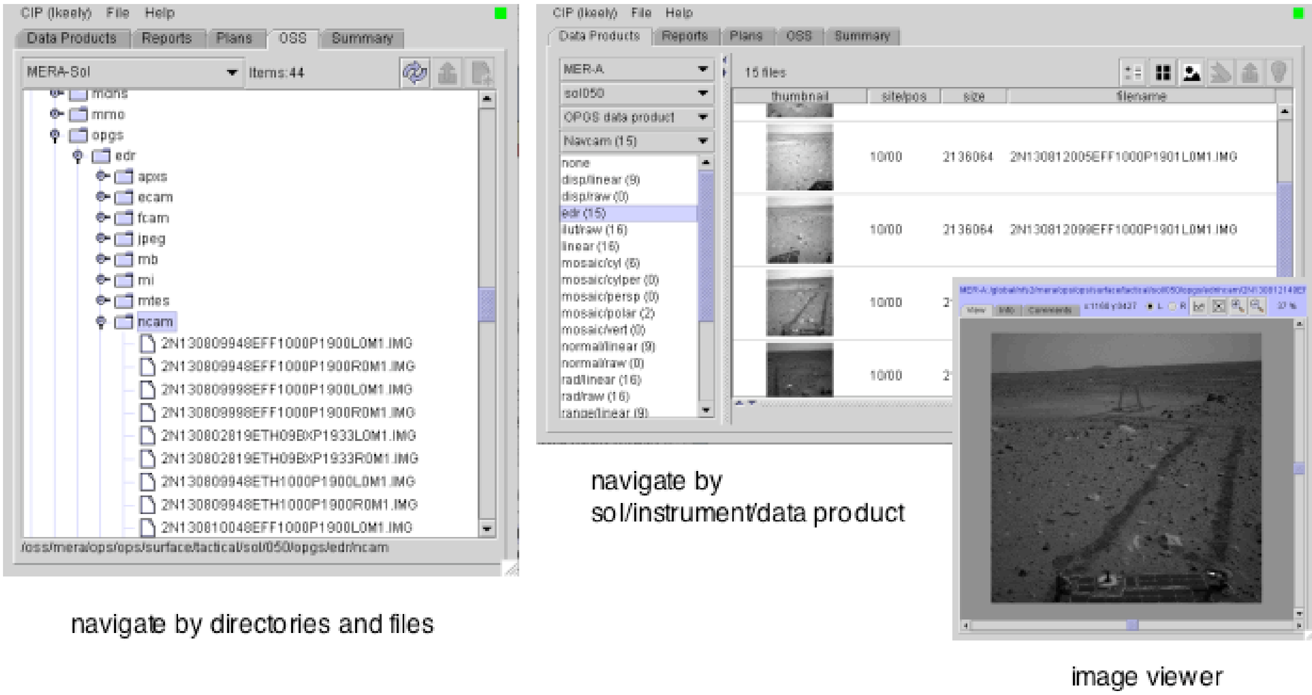


Figure 1.a-8: Multiple data viewing modes

Use of metadata. CIP's data loaders use an innovative algorithm to generate metadata for the downloaded data and images that are stored in the JPL file servers. (We discuss metadata generation in Question 1.c.) Based on this metadata, the Data Navigation tools automatically classify and organize the data and images into hierarchies. The tools use this classification to determine which viewer to use when displaying a file. Users can also do searches on the metadata fields. See Figure 1.a-9.

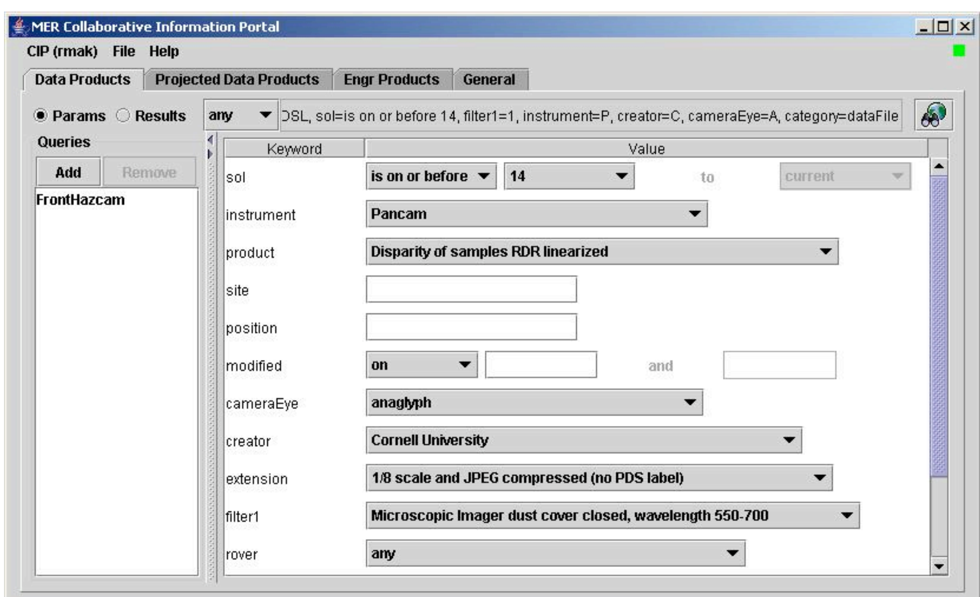


Figure 1.a-9: Searching based on metadata

Restricted viewing. Some data is *ITAR* restricted, and CIP insures that only authorized individuals receive this data. Whenever an authorized user displays ITAR data, the data product viewers show a clear reminder. See Figure 1.a-10.

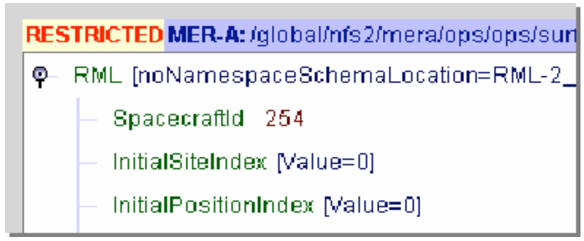


Figure 1.a-10: Restricted data indicator

Clocks

"What time is it?" is important to know for everyone working on the MER mission. The mission runs on Mars time, and since a Martian sol is about 40 minutes longer than an Earth day, regularly scheduled events drift later from day to day relative to Earth time. Moreover, there are two Martian time zones, one per rover.

The CIP application displays clocks that show Martian and terrestrial times in various time zones chosen by the user. The CIP server supplies accurate times, which go over the Internet to the CIP applications. Due to network latencies, the times displayed by the CIP applications can be a few seconds off, which is well within the minute accuracy requirement for clocks. See Figure 1.a-11.

Figure 1.a-11: CIP clocks

It is important to maintain as much accuracy as possible and to ensure that clock displays on multiple co–located CIP applications "tick over" simultaneously. We devised an innovative method to synchronize the clock displays using a central server–supplied time and the local system clock. The method employs a timer for each Mars rover and one for Earth. The timers start at the server top-of-the minute to synchronize all the clocks as closely as possible and to make the clocks tick over at the same time no matter what computer they are running on.

Event Horizon

How long do I have? Mission personnel rely on the Event Horizon tool to count down to the start and end of key events. Knowing when communications passes start and end is especially important to the mission. See Figure 1.a-12.

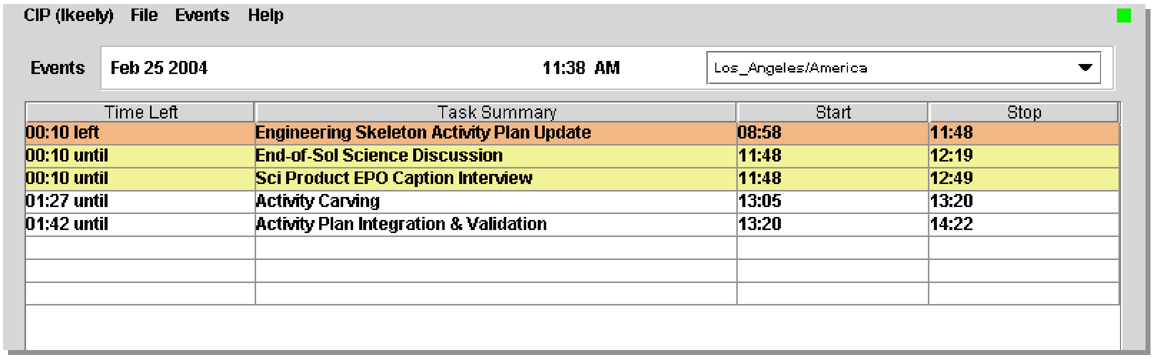


Figure 1.a-12: The Event Horizon tool

Time Converter

The time conversion tool gives mission personnel a handy way to convert between time zones. See Figure 1.a-13.

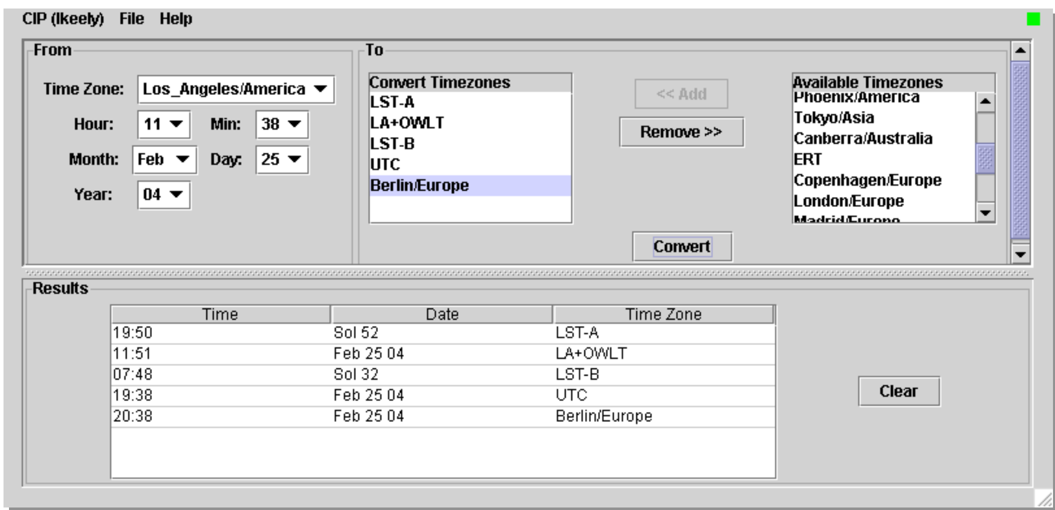


Figure 1.a-13: The Time Converter tool

Broadcast Announcements

The Broadcast Announcements tool allows mission personnel to send messages to other CIP users. Typical messages are new product announcements. See Figure 1.a-14.

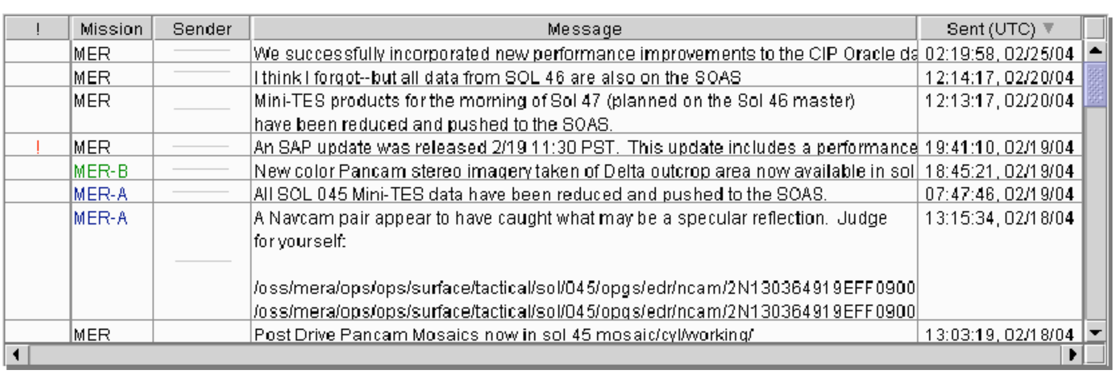


Figure 1.a-14: Broadcast announcements

Multiple computing platforms and interaction models

CIP applications also run on the MERBoard, which presents special challenges. The screen has less "real estate", and it is touch-sensitive. Besides using the mouse, users can use their fingers to click buttons and to drag and drop objects. See Figure 1.a-15.

Figure 1.a-15: MERBoard

CIP accommodates the MERBoard with an innovative adaptive screen layout. It displays larger touch-sensitive objects such as buttons and scroll bars. The user can choose which single CIP function to display at a time, such as clocks only or schedules only.

User feedback

We did not build CIP and its user interfaces in a vacuum. We worked closely with Ames human factors experts. We evolved CIP from early prototypes to its final version by personally participating in a series of Operational Readiness Tests (ORT) at JPL to collect user feedback, which we analyzed and prioritized for each next version of CIP. This process of working closely with users to solicit their feedback is, unfortunately, atypical of most software development projects, and is perhaps CIP's most important user–orientated innovation.

Color coding. It is very important for mission personnel not to confuse the two rovers. Therefore, the mission color–coded the facilities, blue for Spirit and green for Opportunity. We used the same color-coding for various CIP tools, such as the Schedule Viewing tool, the Data Navigation tool, the Broadcast Announcement tool and the clocks. See Figure 1.a-16.

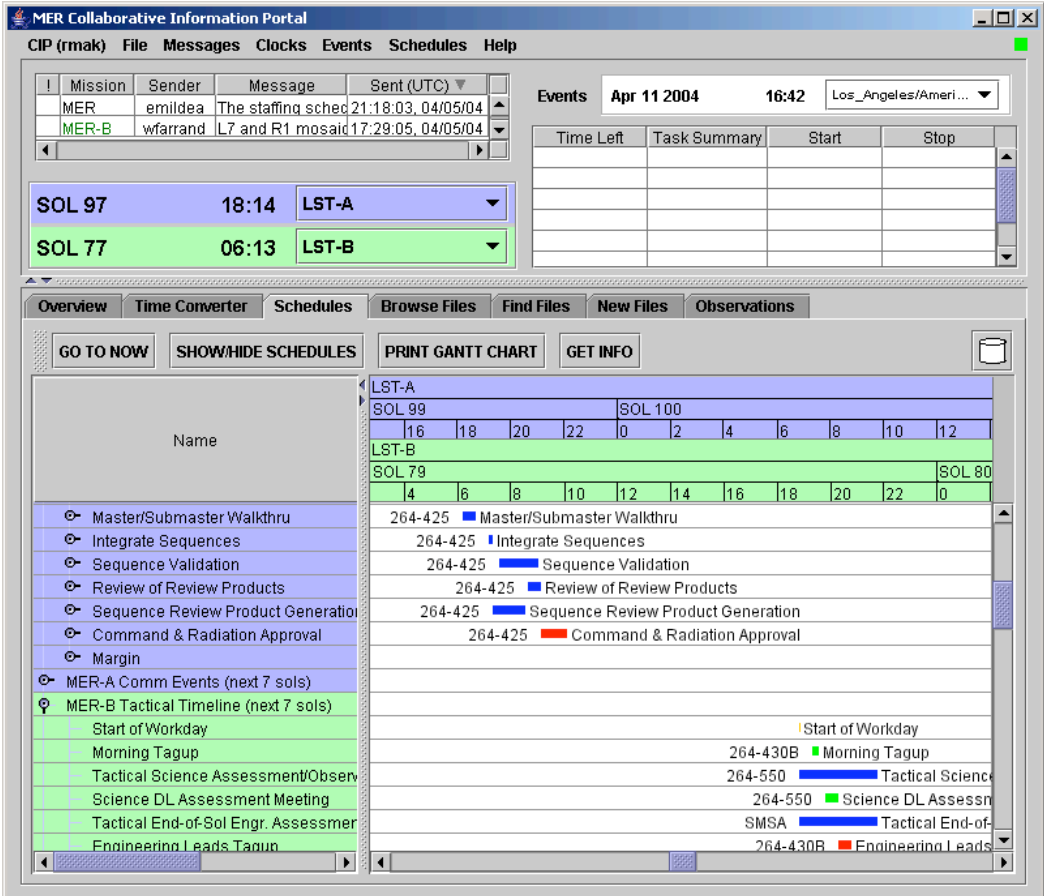


Figure 1.a-16: Color coding by rover: blue for Spirit, green for Opportunity

Networked application. The CIP application is subject to network vagaries. It tries to recover from network failures. During long network operations, it displays a progress meter with a stop button in case the user wants to cancel the operation. If a network operation fails, the network indicator in the upper right corner of the main panel turns red. If the network connection is broken (which happens often with wireless networks), the clocks gray out to indicate that they are no longer receiving accurate times from the server. See Figure 1.a-17.

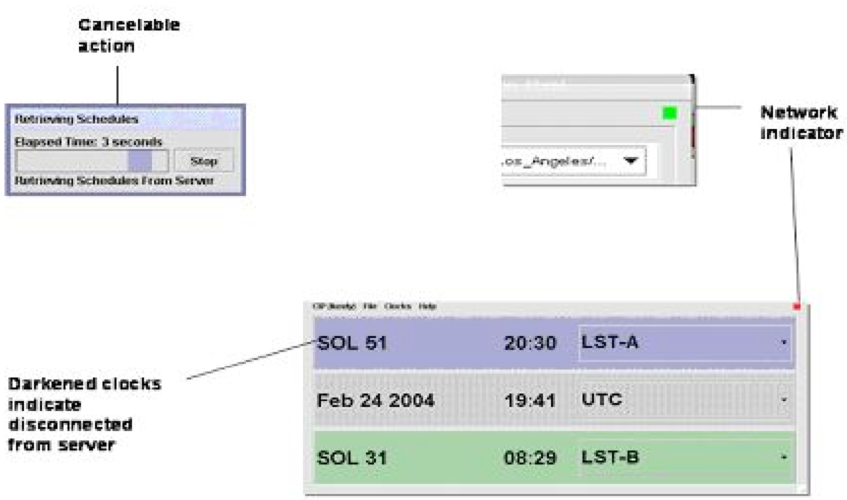


Figure 1.a-17: Network connection indicators

Mission–critical, ubiquitous computing

The managers of the MER mission did not deem Collaborative Information Portal to be Mission–Critical by fiat, but rather CIP earned that ranking by become invaluable to all users everywhere throughout the MER mission. The many user–oriented innovations described above make CIP eminently useful and usable by mission managers, scientists, and engineers.

In Question 1.c., we'll describe the other side of ubiquitous computing — being used everywhere — and our architectural innovations that make it possible.

b. *In what NASA program, project or mission has this contribution been used or will be utilized and to what extent*? (*include any non-aerospace commercialization applications)*

We designed and developed CIP for the MER mission, and so far, that has been its only mission. Mission personnel in various roles use CIP both inside and outside of the mission control room, and both on and off the JPL campus. There are over 330 registered CIP users, and over 250 copies of the CIP application installed on desktop or laptop computers. CIP's middleware also supports two other MER applications.

CIP is the primary time management tools for the mission, both for operations and for science. CIP times and coordinates all communications events inside the mission control room. CIP is a key tool for retrieving rover data and images through JPL's mission firewall. As of March 31, 2004, CIP had downloaded over 100 GB to users' local desktop and laptop computers.

As CIP was participating in the series of Operational Readiness Tests at JPL prior to the rovers' landings, the mission managers became increasingly aware of its usefulness and the importance for the mission's success. Although it was not in its original specifications, the mission managers deemed CIP to be Class A, Mission–Critical software.

Inside the mission control room

There are always two MERBoards in the front of the Surface Mission Support Area (SMSA, or the mission control room) that display CIP clocks, usually the two Mars times (one in each rover's time zone) and Earth time UTC. The flight director often has a CIP schedule displayed on several of the large wall screens. This is a schedule for Spirit or Opportunity, depending on which rover is currently active — either a tactical timeline schedule (daily operational events such as meetings) or a communications event schedule (uplinks and downlinks).

Many of the control room engineers have CIP applications running on their workstations. They can display a schedule of the currently active rover similar to the one up on the big screens, or perhaps a staffing schedule that shows who is working where, when, and in what role. The engineers also use the Time Conversion tool to convert between Mars and Earth times.

Elsewhere at JPL

Each of the two sequencing rooms has a MERBoard that displays CIP clocks or schedules. Each of the two science assessment rooms has several MERBoards displaying CIP clocks or schedules. A mission scientist can walk up to a MERBoard and use other CIP tools, such as the data navigator. A MERBoard displays CIP clocks inside JPL's Von Karman auditorium during official MER press conferences.

Mission scientists and researchers who have offices at JPL and who are registered CIP users (i.e., they have accounts) use CIP on their desktop or laptop computers.

Outside of JPL and throughout the world

Mission scientists and researchers who have accounts can use CIP on their desktop or laptop computers at their homes, offices, or schools — anywhere in the world — as long as they also have VPN access into JPL. For these users, CIP is their primary means of keeping track of Mars time, viewing the current schedules, and receiving broadcast messages. Most importantly, CIP allows them to download rover data and images through JPL's mission firewall to their local computers for viewing and saving.

Support for other applications

Besides the CIP application, the CIP middleware also supports two other major MER applications.

Viz is an application developed at Ames that allows its users to view and rotate 3D images taken by rovers. It uses the CIP middleware to authenticate its users and to download the images. Viz was written in C++, but since the CIP middleware's web services interface is language-independent, Viz is able to request middleware services and use the results.

Quill is a mission report generator written at JPL in Java. It also uses the CIP middleware to authenticate its users.

By having the CIP middleware authenticate users for the CIP, Viz, and Quill applications, each user of these applications only needs to have one user name and one password for all three.

c. *Provide details describing how the contribution works or operates relative to system, subsystem, components, etc.*

In Question 1.a, we described how our user–oriented innovations enable CIP to achieve one side of ubiquitous computing: Everyone uses CIP. Now we describe how our architectural innovations enable CIP to achieve the other side of ubiquitous computing: CIP is used everywhere.

"CIP is used everywhere" — Architectural innovations

CIP's service–oriented architecture enables it to be used everywhere. We designed an innovative three–tier enterprise architecture to meet the goals of scalability, reliability, extensibility, and security. Partitioning the application into a client tier, a middleware tier, and a data repository tier balances and distributes the computational resources. A centralized set of servers provides services to all the CIP client applications. See Figure 1.c–1.

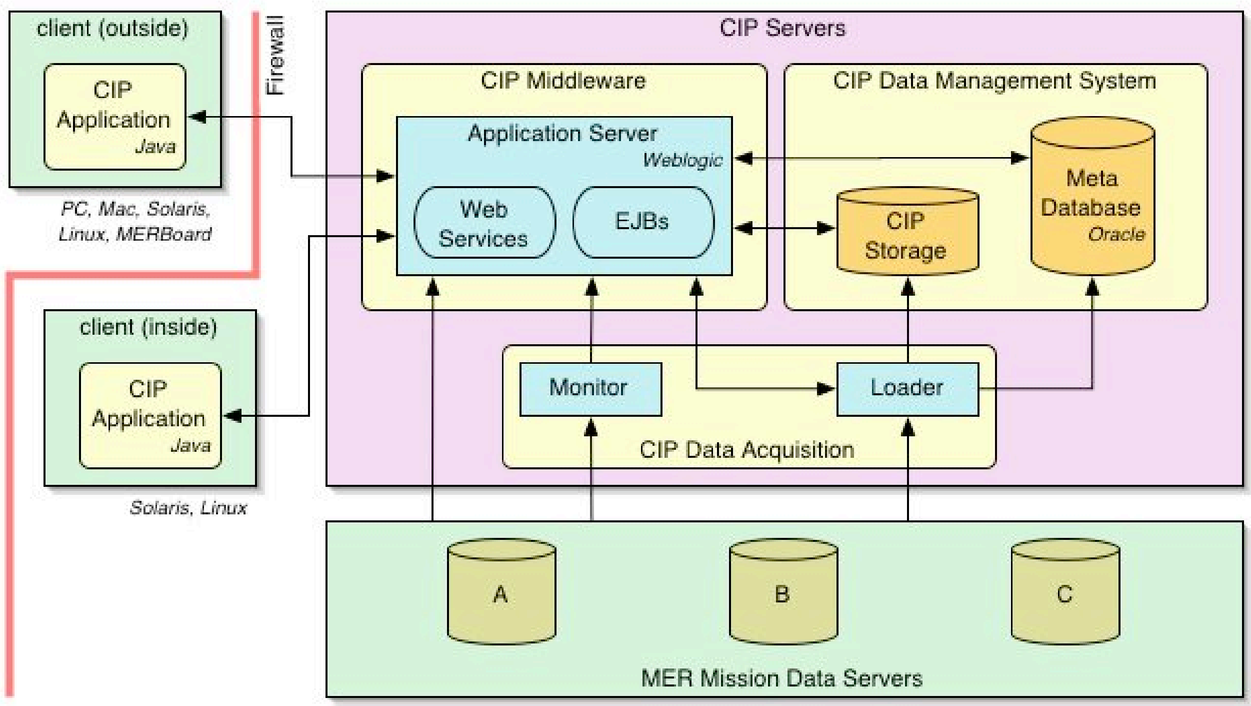


Figure 1.c–1: The CIP architecture

The architectural innovations that support ubiquitous computing include:

- Designing CIP to be a three–tier enterprise application.
- Adhering to industry standards.
- Using commercial off–the–shelf software.

- Using web services as the interface between the client applications and the middleware.
- Extensive runtime logging, real time monitoring, and stress testing of the middleware.
- Dynamically reconfigurable services.
- A separately managed data repository tier.
- Using JMS for asynchronous messaging.
- Components in the three tiers communicate with each other over the network. The three tiers are:
    - Client application
    - Middleware
    - Data repository

Web services are the interface between the client application and the middleware. Asynchronous messaging occurs among components within the tiers.

The client application tier

Users run the Java-based CIP client application on their desktop or laptop computers. Hence, there can be many copies of this application running simultaneously, one or more per user who is currently logged in.

The CIP application is a “thick client” application that runs by itself, as opposed to a “thin client” application that runs within a web browser. A thick client application makes better use of the user’s computer and provides better interactivity and responsiveness. It contacts the middleware over the network only whenever it needs to request a service, such as in response to a user action. It polls the middleware periodically for the current time and for any new broadcast messages.

We implemented the client application using the widely available Java platform. This makes it possible to easily install and use the client on almost any desktop or laptop computer. It runs on PC computers (Microsoft Windows 2000 and XP), Macintosh computers (MacOS X), Linux and Solaris computers, and the MERBoard. We used graphical user interface components from the Java Foundation Classes, commonly known as “Swing”.

The CIP client application provides the following tools in an integrated user interface:

- *Schedule Viewer* for viewing current event and staff schedules.
- *Clocks* for displaying date and time in any Earth or Mars time zone.
- *Time Converter* for converting dates and times between time zones.
- *Event Horizon* for displaying count down timers for events selected from the schedule.
- *Broadcast Announcements* for announcing mission related information to all CIP users.
- *File Navigation* for browsing files on the central mission file server, finding files using the CIP data repository, and for notification of the arrival of new files.

With a component based architecture, each client tool is a CIP Component object. Service Manager objects support the CIP Component objects. Each Service Manager object manages connections to a particular middleware service. See Figure 1.c–2. For example, the clock components use the Time Manager object, which manages the connections to the middleware’s time service.

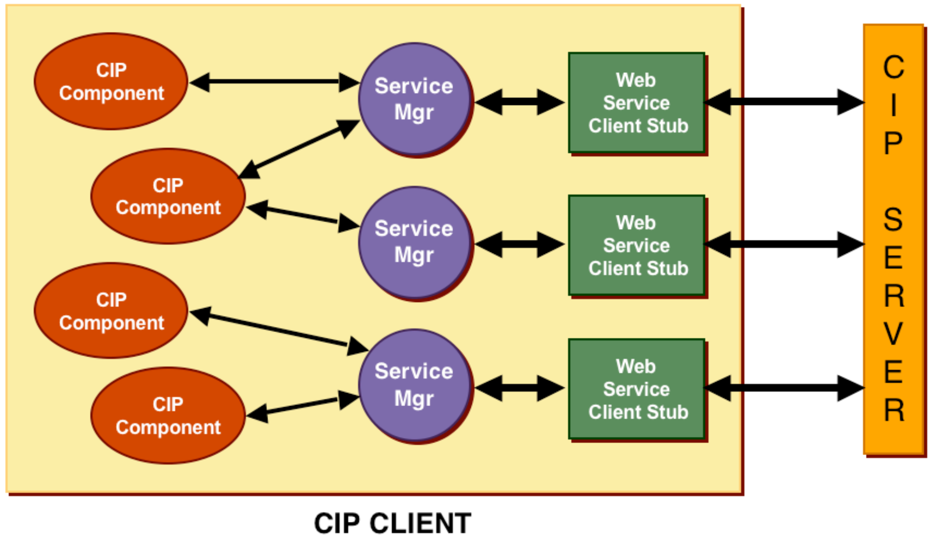


Figure 1.c–2: The CIP client application architecture

Schedule Viewer

The Schedule Viewer tool provides a mechanism for users to view mission schedules. Each user has a customizable set of schedule retrievals. Users may select or create schedule database query retrievals; or they the may create schedule file read retrievals. The tool uses a service manager to interact with the middleware schedule query service. All middleware transactions are processed in a separate thread and are cancelable by the user.

The retrieved schedule data is turned into a unified schedule as described earlier in section 1.a. The tool uses customized SWING components to display the schedule and ancillary dialogs. A customized Tree-Table is used for schedule viewer's left-hand-side and a customized Table is used for the right-hand-side Gantt view. A split pane allows users to show more or less of each view. The timescales above the Gantt chart are customizable by time zone and time span. Users may move through time by using a customized scrollbar at the bottom of the Gantt chart. By default, the system will keep the current time, now, centered in the display. The tool uses the time service manager to know what the current time is as well as to receive the top of the minute tick.

The schedule data structure and table cell renderers were designed to achieve real-time update rates while the schedule is being scrolled as well as small memory footprint.

The schedule viewer listens to the schedule message channel and notifies users of schedule database updates.

Clocks

The Clocks tool provides a customizable set of multi-planetary clocks synchronized on the CIP server for accuracy. Each clock listens to the time manager for updates. The time manager utilizes timers for generating tick events for a given planetary time unit. The timers operate on earth milliseconds with a server base time. The clock face is formatted by a custom calendar component that is able to convert Earth time to Mars time and back.

Time Converter

This tool provides a conversion from one time zone to another. The time entered by the user is converted to times in one or more selected time zones using the custom calendar component mentioned previously.

Event Horizon

Event Horizon provides a countdown timer to important events that the user has selected from the schedule viewer. It listens to the time service manager for time updates and displays the start, stop and time left for the event in a table view using a custom renderer.

File Navigation

The CIP file navigation tools include browse panels for OSS, the central file system, browse, search, and notification panels for the CIP metadata base, and download panels. Also included are viewers for a number of different types of file formats including HTML, JPEG, TIFF, text, and proprietary data formats.

Based on user requests, these tools query the middleware services through the file manager to retrieve file metadata and content. The results are displayed in various viewers.

Using Java components, file system views of the OSS are presented in a tree form, each directory a branch. Opening a branch invokes a query to the server for the contents of that branch.

The file metadata browser reduces the complexity of navigating data files and reports scattered across an entire file system. File metadata is selectable by rover, sol, instrument, and data type from a list of menus. The tool queries the CIP metadatabase and presents the results and file counts from the server in a table view.

The table view was developed with custom renderers in conjunction with Java components. Included in this view are configurable columns containing image thumbnails, file size, and custom information from file headers such as image elevation and azimuth. To avoid blocking other CIP tools during network I/O, the viewer executes in a specialized thread separate from the main application event thread. This thread can be canceled by users and interleaves the display of thumbnail files as they arrive from the server.

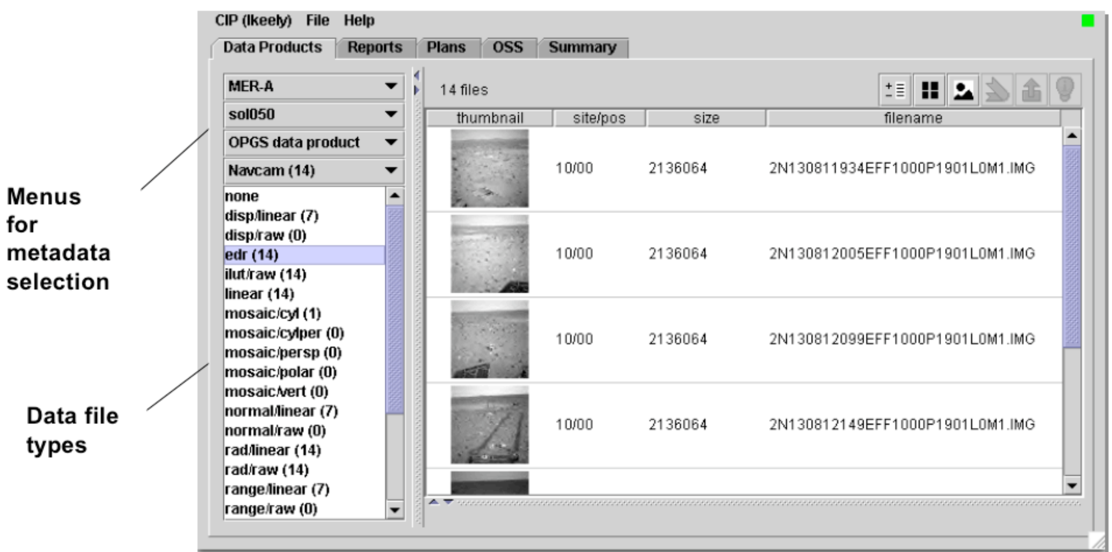


Figure 1.c-3: File metadata in table view

Data files are decoded with a custom codec and displayed in a custom image viewer developed for CIP using the Java image and other 2D graphics classes. The Sun JAI codec is used for GIF, TIFF, PNG, and JPEG images. For report files, a custom text viewer and a COTS embeddable HTML viewer are used.

Users may choose to be notified of new file metadata in the database. For this feature a file navigation tool called New Files listens to the message service manager for new file events occurring within a user specified time window and then queries for the metadata, displaying the response in the table view described previously. The tool periodically removes files from table that are too old for the time window and keeps a count of new files by instrument.

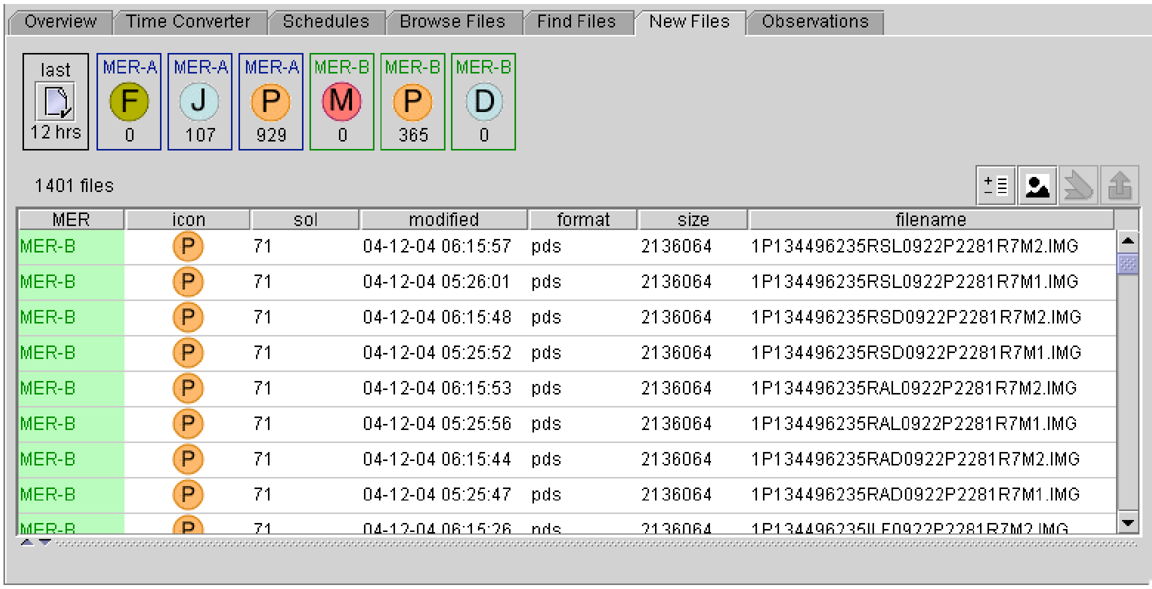


Figure 1.c-4: New Files view

The middleware tier

The CIP middleware is server software that runs on a separate computer. It communicates over the network with all the actively running copies of the CIP application, and it sits in the middle between the client applications and the data that they request. The middleware includes a Java-based, commercial off-the-shelf application server and Java components developed for CIP. We designed it around two industry standards, Java 2 Enterprise Edition (J2EE) and web services.

The J2EE-based components ("beans") we developed for the CIP middleware are Enterprise JavaBeans (EJB). At run time, the EJBs operate under the control of the WebLogic application server from BEA Systems, Inc.

The middleware contains three types of EJBs:

- *Stateless session beans* that do not maintain any state information. Therefore, the application server can keep them in an instance pool for use as needed by any client.
- *Stateful session beans* that maintain state information on behalf of clients. The application server keeps them in a memory cache.
- *Message–driven beans* that process asynchronous messages.

The middleware provides services to the various tools of the client applications. Client applications request services from the middleware, which returns responses to each request. The CIP middleware services are:

- *User management service* to process user logins and logouts and to maintain user sessions.
- *Time service* to provide Earth and Mars times in various time zones.
- *Metadata query service* to fetch metadata from the databases.
- *Schedule query service* to fetch schedules from the databases.
- *File streaming service* to download and upload files.
- *Message service* for asynchronous notification and broadcast messages.

Service Providers

One or more stateless session EJBs represent each service. Each Service Provider EJB has public methods that client applications can invoke remotely over the network to request services. The application server maintains an instance pool of these stateless beans – it creates or destroys these instances in response to the request load. This makes CIP scalable. As more requests arrive from the users, the application server automatically replicates more Service Providers to handle them.

Web services

A key middleware innovation is the use of web services. As shown in Figures 1.c–2 and 1.c–5, client applications use web services to communicate with the remote Service Provider EJBs. Each client Service Manager object has a web services client stub that is the proxy for the remote bean.

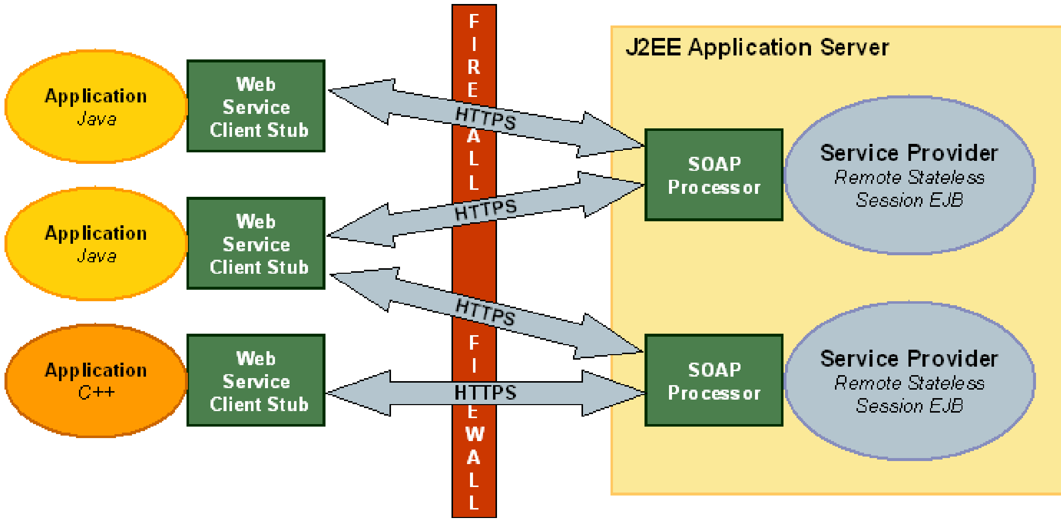


Figure 1.c–5: Web services and Service Provider EJBs

Whenever a client application needs to request a service, it does not connect directly to the Service Provider EJB in order to make a remote call to one of its public methods. Instead, the application makes a local call to a method with the same name in the client stub. The stub converts the call to a service request in the form of a text document encoded in the XML-based SOAP protocol. The stub sends this document to the middleware server using the Web's encrypted HTTPS protocol. The SOAP processor of the target Service Provider EJB decrypts the request and invokes the appropriate public method of the bean.

The response generated by the target Service Provider EJB returns similarly across the network to the requesting client application as an encrypted SOAP document. The client stub decrypts the response and converts it to Java objects for the client application.

The net result of using web services is that a client application makes local calls to the client stub and gets local results back from the stub. Web services handle all the details of connecting to the remote Service Provider EJB, encryption and decryption, and sending requests and responses across the network. Web services have the additional important benefit of meeting JPL's security constraint that prohibits maintaining persistent connections, and the encrypted requests and responses get through the mission firewall.

We made CIP very extensible by organizing each middleware service as a separate combination of web services and a Service Provider. It is very easy to "plug in" new services and to replace or remove obsolete ones.

Data objects

Several of the middleware services create data objects, which are stateful session EJBs. Because these objects maintain state information, the application server caches them in memory.

A client application that wishes to download a file from the mission file system sends an initial request containing the file path to the middleware's streamer service. The streamer service's Service Provider EJB creates a streamer data object. The data object can read the file in 64K blocks and keep track of how much of the file it has already read. The client application then makes a series of requests for data blocks, which the streamer Service Provider bean fulfills one block at a time from its data object. By properly managing all of the data objects, the streamer service can handle simultaneous downloading requests from multiple client applications.

Caching query data

The metadata and schedule query services also create data objects. These data objects use Java Database Connectivity (JDBC) calls to query the Oracle databases. Each data object keeps a reference to the returned query results.

By taking advantage of the application server's memory cache of data objects, the query services can greatly improve the performance of repeated requests for the same data. As shown in Figure 1.c–6, a registry keeps track of which query data objects are in the cache. This registry is a hash table whose keys are the query statements and whose values are references to the corresponding data objects. Then whenever a query request arrives, the query service first checks its registry. If the data is already in the cache, the service does not need to make the much more expensive database query.

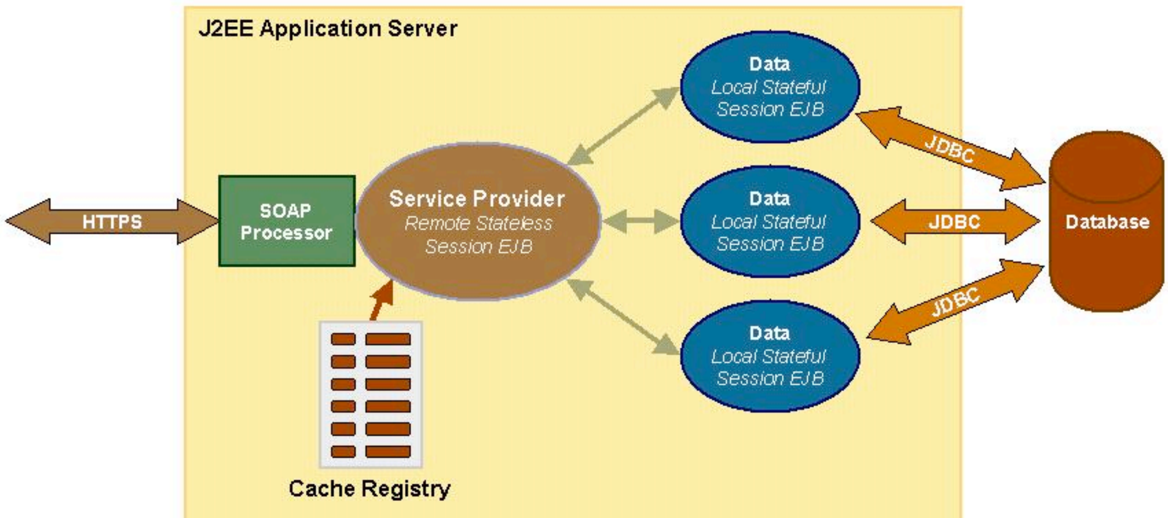


Figure 1.c–6: Query data objects and the cache registry

Whenever the database is updated, it is important to ensure that stale data does not remain in the cache. The CIP middleware uses a very simple algorithm to maintain the integrity of the cached data. Whenever the data loader in the data repository tier updates a database, it notifies the middleware. The middleware flushes all the entries for that database from the registry. New entries for that database are subsequently created when client applications make query requests.

Such a flushing algorithm is effective only if the database updates occur infrequently. The original specifications for CIP stated that updates would occur at most several times a day. During the actual mission, this has been true for schedule updates, and the cache hit rate for schedule queries is over 94%.

However, during the mission, metadata updates have occurred as often as several times a minute (at times as high as once per second). With metadata entries constantly flushing out of the registry, it is counterproductive to keep checking the metadata cache, since nearly all the requests has to go to the database anyway. Fortunately, our design of the metadata service makes it simple to reconfigure the service dynamically to ignore the cache, and doing so has actually improved performance for metadata requests. (We'll describe dynamic reconfiguration in detail below.)

Reliability

Because the application server monitors the behavior of the EJBs and does automatic retries or error recovery, the middleware is very reliable. Our key innovations that increase reliability include:

- Extensive runtime logging
- Real time monitoring
- Intensive stress testing

The middleware logs every activity, such as a user request. For each user request, the log entry contains a timestamp, the user's name, the name of the called method, details of the request, and key information about the results. Figure 1.c–7 shows sample log entries.

```
2004-04-01 12:09:32,225 INFO : jdoe: Metadata.query()
2004-04-01 12:09:32,230 DEBUG: SELECT file_view.* FROM MER_B.file_view WHERE
((file_view.modified >= 1080806949117) AND (file_view.category = 'dataFile')
AND (file_view.filename LIKE '/%/merb/ops/ops/surface%/%/rcam/%' ESCAPE
'\'))
2004-04-01 12:09:33,126 DEBUG: Records fetched: 0, skipped: 0
2004-04-01 13:50:06,816 INFO : mjane: Metadata.query()
2004-04-01 13:50:06,820 DEBUG: SELECT file_view.* FROM MER_B.file_view WHERE
((file_view.seqnum = 66) AND (file_view.category = 'dataProduct') AND
(file_view.owner = 'opgs') AND (file_view.type LIKE '%/jpeg/MER-B' ESCAPE
'\'))
2004-04-01 13:50:10,073 DEBUG: Records fetched: 1, skipped: 0
2004-04-01 13:50:11,546 INFO : jdoe: Metadata.getObjectsByParent()
2004-04-01 13:50:11,550 DEBUG: SELECT * FROM MER_B.file_view WHERE
(parent_pk = 16127) AND (category = 'dataFile')
2004-04-01 13:50:12,108 DEBUG: Records fetched: 5, skipped: 0
```

Figure 1.c–7: Sample log entries

We can "mine" these logs afterwards to compute various statistics (such as how frequently users accessed certain types of files) or to deduce usage patterns (such as what methods users employed to locate data products).

We developed separate utility program to constantly monitor the middleware's status and graphically report such statistics as memory usage and response times. See Figure 1.c–8. Knowing the health of server at all times enables the system operators to correct problems before they became serious.

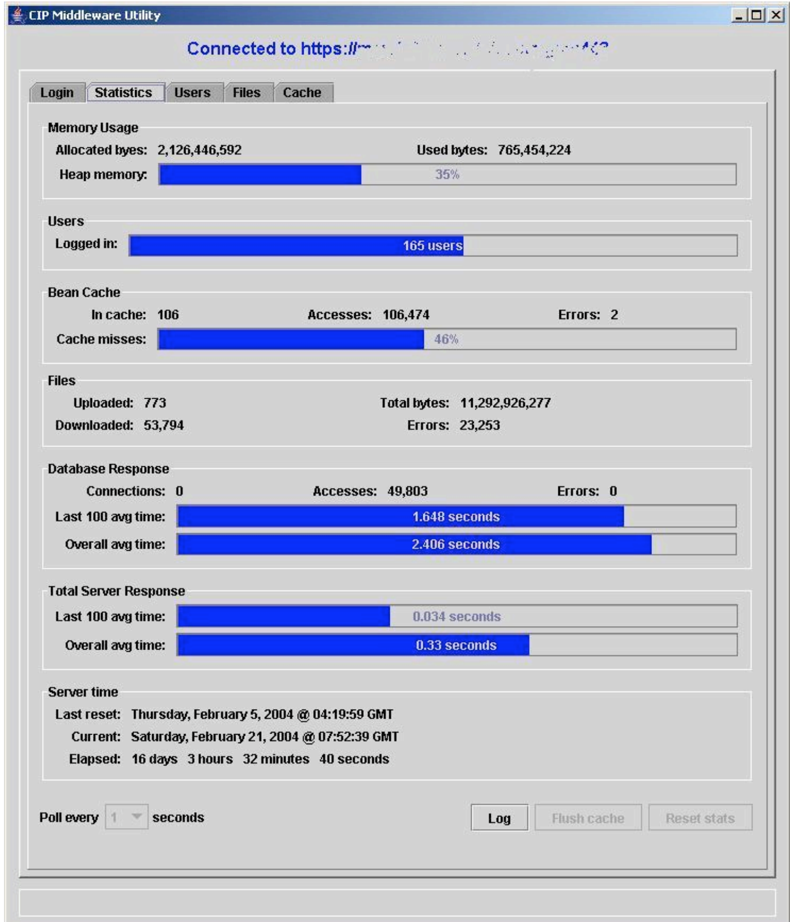


Figure 1.c–8: Monitoring the middleware in real time

We put the CIP middleware under intensive stress testing before we ever deployed it into operation. This testing pointed out performance bottlenecks and helped ensure that CIP would be able to handle heavy loads. We developed a standalone, interactive utility to perform the stress testing by simulating any number of users performing various client functions, such as accessing schedules or downloading files. See Figure 1.c–9.

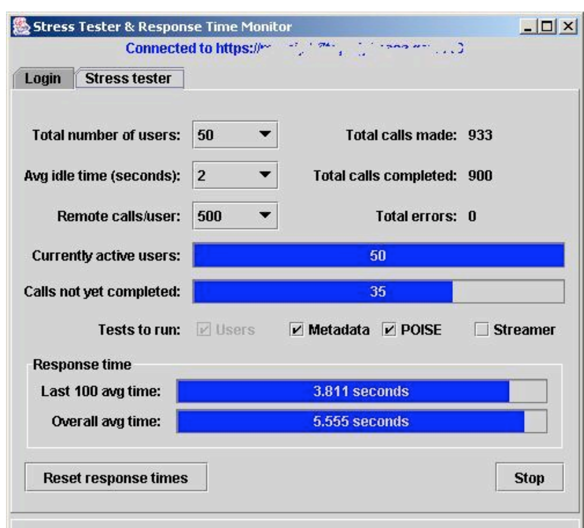


Figure 1.c–9: The stress tester

Dynamic reconfiguration

An important measurement of software reliability is how long it stays up and running. An application can unexpectedly crash, or system administrators can bring it down for maintenance. A common maintenance operation is to reconfigure an application to meet some change in daily operations, such as moving some critical system file from one directory to another, or updating the time it takes for a signal to travel from Earth to Mars (one-way light time).

A key innovation that allows CIP to stay up and running for long periods (over 41 days at a time) is dynamic reconfiguration. CIP's middleware design allows individual services to be hot redeployable. In other words, we can restart a service while the rest of the middleware (and CIP as a whole) continues to run.

To reconfigure a service, a system administrator first edits the service's configuration file (for example, to change the one-way light time) and then redeploys the service. When the service restarts, it reads in its new configuration. Redeploying a service typically takes only a few seconds, and often users will not notice any interruptions.

Security

CIP security is a combination of user management and data encryption. The middleware requires each user to log in with a user name and password. Each user has pre-assigned privileges that allow or disallow access to certain data or images. Another commercial off–the–shelf product, digital certificates from Verisign, enables the CIP middleware to encrypt all data traffic between it and the users' client applications.

CIP has to comply with JPL's security constraints. As mentioned earlier, using web services allows CIP to get information through the mission firewall. Web services also do not use persistent client connections, which are security risks.

The data repository tier

The data repository tier encompasses the Oracle databases and the MER mission file system, which run on separate computers. The tier also includes three key Java-based utilities:

- File Monitor that constantly watches the mission file system for file creations or updates.
- File Detector that sweeps over the mission file system to look for newly created or updated files.
- Data Loader that creates metadata about data or image files, and then inserts or updates the metadata in the database.

See Figure 1.c–10.

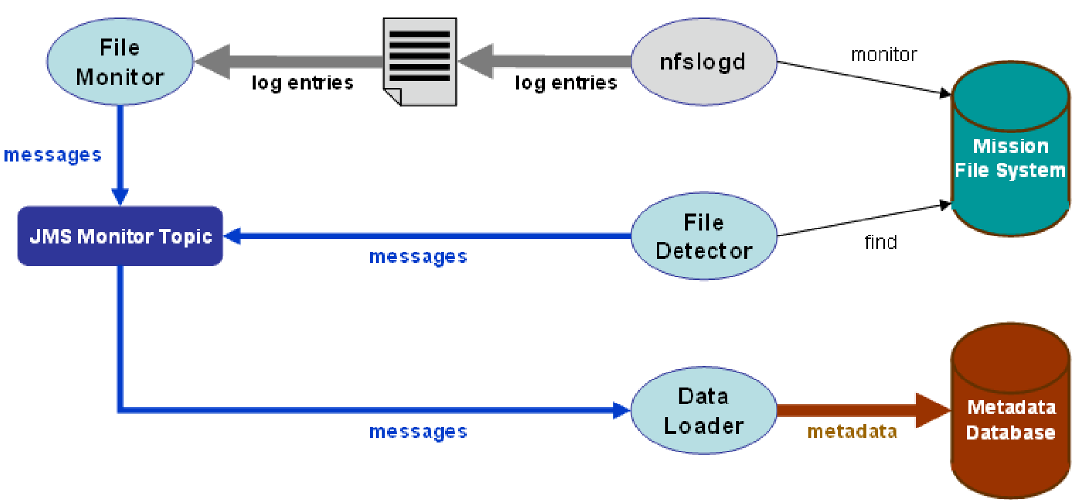


Figure 1.c–10: The data repository tier

File Monitor constantly watches the logs generated by the Unix utility program *nfslogd*, which writes a log entry every time a file is created, read, moved, or updated. The monitor uses a configuration file that contains regular expressions (patterns) of file paths that are relevant to CIP. It filters out (ignores) any files whose paths do not match any of the expressions.

Unlike File Monitor, File Detector uses the Unix utility program find to "walk" the directory tree of the mission file system and find any relevant newly created or updated files. It also uses a configuration file that contains regular expressions of file paths. File Detector walks the directories once during each run. It is a backup for File Monitor whenever *nfslogd* is not running.

Metadata generation

As soon as File Monitor or File Detector encounters a relevant newly created or updated file, it sends a message to Data Loader. Data Loader generates metadata for that file. Using regular expressions from a configuration file, a characterization agent derives metadata field values from the file path itself. The agent also obtains some information from the Unix file system and for some types of files, it reads the file header to get more metadata field values. Example metadata fields include the file name, the creation date and time, which rover the file belongs to, which rover instrument generated the file data, during which sol, the rover location, etc. See Figure 1.c–11. Data Loader inserts or updates the metadata in the database. The characterization agent is also employed by the middleware to provide file system metadata directly to the client.

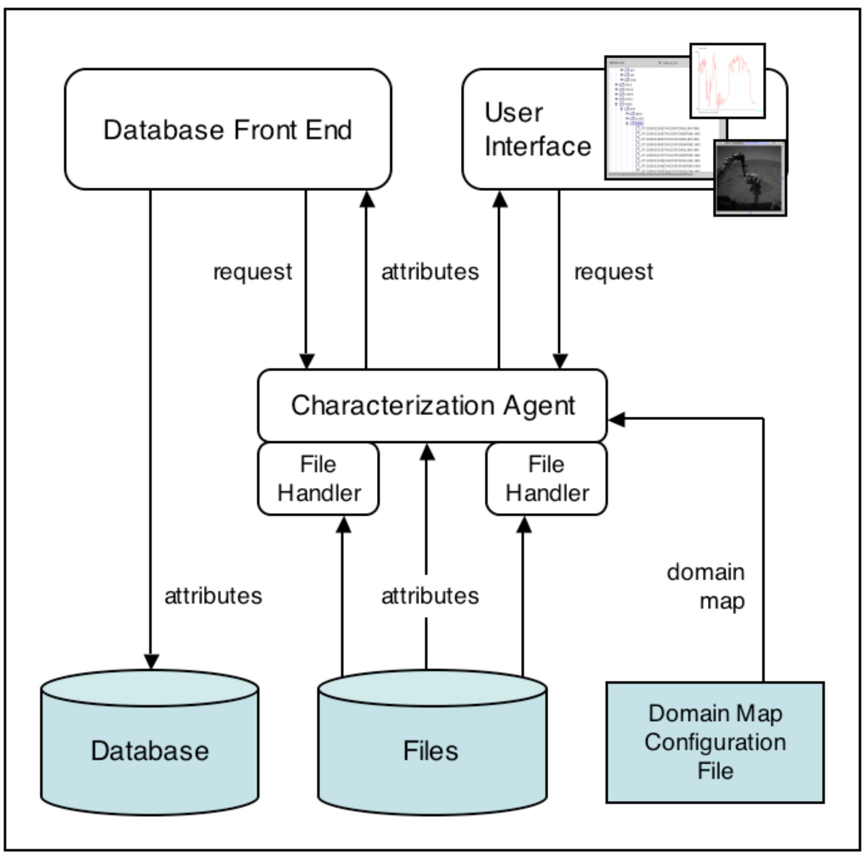


Figure 1.c–11: Metadata generation

Asynchronous messaging

CIP has two types of asynchronous messages:

- *Notification messages* that inform the CIP middleware or CIP users that new data and image files are available.
- *Broadcast messages* that CIP users can send to all the other users.

To implement asynchronous message, the CIP middleware uses the Java Message Service (JMS), which is a part of the BEA WebLogic application server.

JMS uses a *publish–subscribe* model. The middleware has a number of topics that represent different types of messages. A message consumer (such as a CIP client application) registers its interest in one or more topics. Then whenever a message producer (a CIP client application or another CIP component) publishes (sends) a message to that topic, JMS will deliver the message to all the message consumers who are interested in that topic. CIP messaging is asynchronous — message queuing and delivery occur in parallel with all other operations.

Figure 1.c–12 shows how the file monitor notifies client applications that are interested in panoramic camera images.

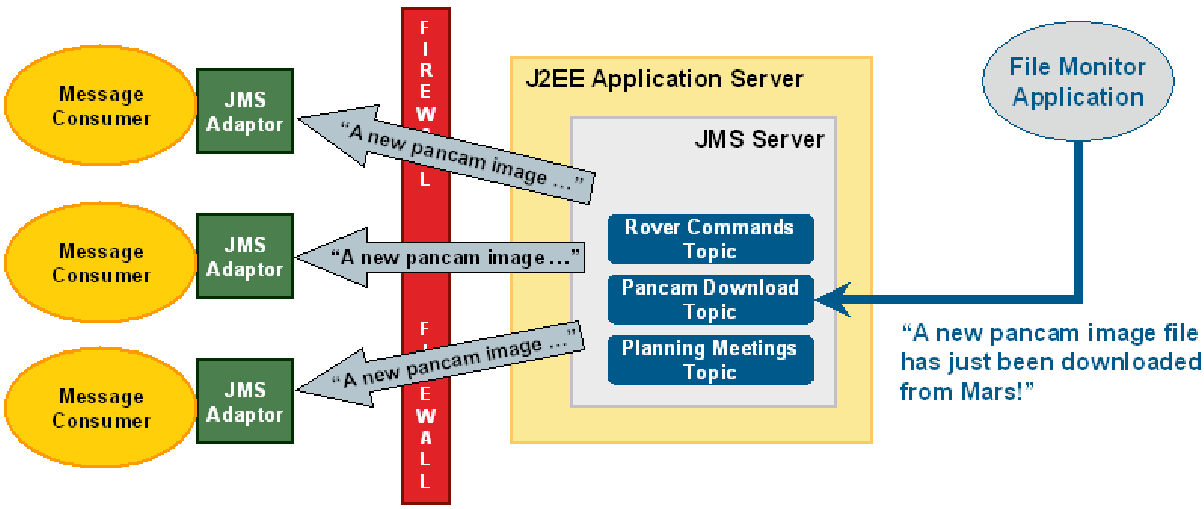


Figure 1.c–12: Asynchronous messaging

Figure 1.c–13 shows how a broadcast messages topic, in which all CIP applications are interested, enables one user to send messages to all the other users. The Message Archivist, a message–driven EJB in the middleware, archives all broadcast messages into a database. The middleware's message service enables users of the CIP client application to browse all the archived broadcast messages.

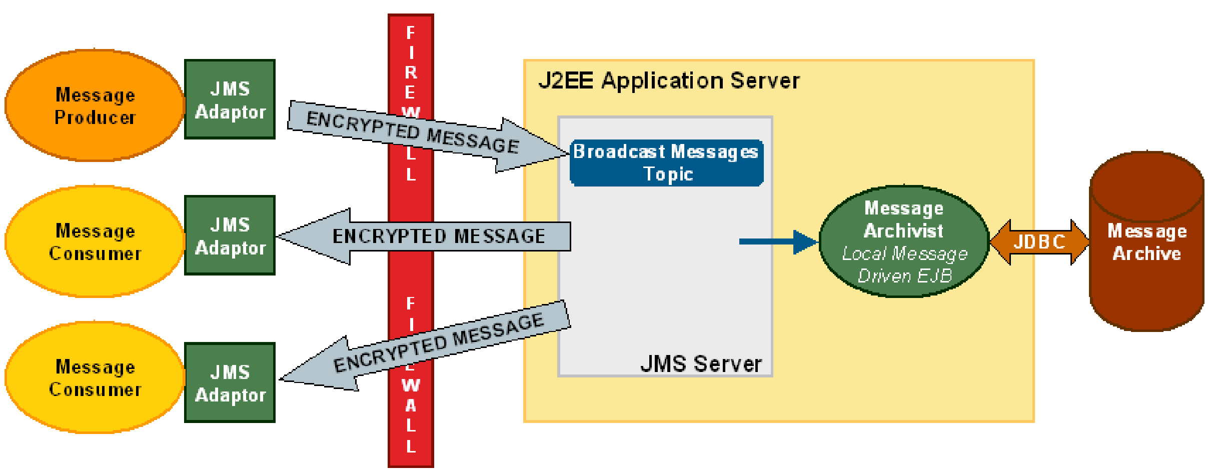


Figure 1.c–13: Broadcast messages and the message archive

CIP applications receive their messages via web services. Each application has a "mailbox" that the middleware maintains to receive messages. The application polls its mailbox periodically by making web services requests, and it receives any delivered messages in response.

2. SIGNIFICANCE.

a. *Explain why the contribution is significant: scientifically, technologically, or from a humanitarian viewpoint, to the aeronautics, space community, and non-aerospace commercial activities.*

CIP is Class A, Mission–Critical software for the MER mission. Mission personnel of various roles — managers, technicians, engineers, scientists, and researchers — use CIP at all locations — inside the mission control room, within JPL, and worldwide outside of JPL, in users' offices, homes, and hotel rooms.

CIP is the master clock and the keeper of the master schedules for the mission. Inside the mission control room at JPL, two MERBoards up front display CIP clocks that show times in various Earth and Mars time zones. The big wall screens display CIP schedules. Mission technicians and engineers often display CIP clocks, schedules, and other tools on their workstations. See Figures 2.a–1, 2.a–2, and 2.a–3. The science rooms at JPL often have MERBoards and wall screens displaying CIP clocks and schedules. Scientists and researchers everywhere use all the CIP tools on their desktop and laptop computers.

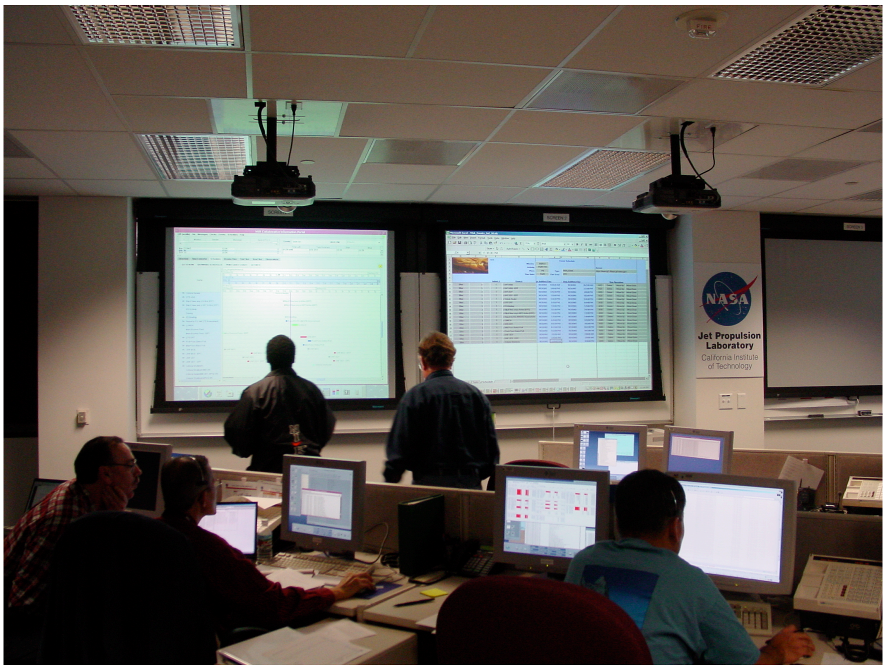


Figure 2.a–1: A CIP schedule and the Schedule Creation tool in the mission control room

Figure 2.a–2: CIP clocks on the front MERBoards in the mission control room

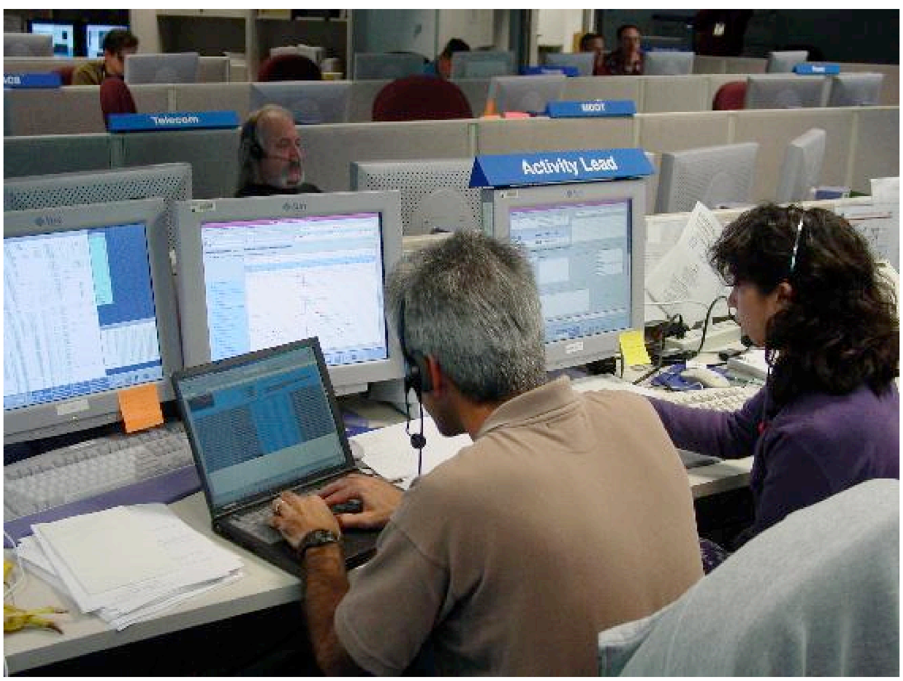


Figure 2.a–3: A CIP schedule, the Schedule Creation Tool, and the Time Conversion tool in the mission control room

The mission runs on Mars time in two Martian time zones, one per rover. There are two separate sets of events and meetings. Each rover has its own team of people fulfilling various roles; often one person may change roles during a sol, and some people move between the two teams. CIP schedules are crucial for letting everybody know precisely when events (such as command uplinks or data downlinks) or meetings will occur.

Users can each select pertinent events and meetings from the schedule and enter them into the Event Horizon tool. Each item in the Event Horizon table has a timer that counts down the number of minutes until the start of the event or meeting. An item turns yellow, and then red, as the start time approaches. CIP makes it hard to miss an important event or meeting.

Mission scientists and researchers need to browse the mission file system, search for data products, and download data and images to their local workstations and laptops. CIP allows them to do so while still abiding by JPL's security constraints. The CIP middleware authenticates each user and authorizes each data access based on the user's privileges. For example, it does not allow foreign users to access any ITAR–restricted data. If a user has the privileges to download some data or an image, CIP gets it through JPL's mission firewall.

The mission personnel need to collaborate with each other, even if they are located throughout the world. CIP allows a user to send a broadcast message to all the other users. A user can attach comments to data files and images that other users can read and add their own comments.

The nominal mission for each rover lasts only 90 days, and yet each has already accomplished much, with still more to come. CIP continues to be a significant and critical tool to ensure that during this time, mission personnel work together efficiently and effectively.

b. *Estimate the degree of scientific or technological significance by a mark on the line below:*

0___________1_______________2___________________3_________________4_________X_______5

None ***Modest*** ***Average*** ***Major*** ***Maximum***

c. *Estimate the significance of the contribution relative to a specific NASA program or mission by marking the line below:*

0___________1_______________2___________________3_________________4_________X_______5

None ***Modest*** ***Average*** ***Major*** ***Critical***

3. STAGE OF DEVELOPMENT.

Indicate the stage of development of the contribution by a mark on the line below:

0___________1_______________2___________________3_________________4_________X_______5

Concept ***Simulated*** ***Tested*** ***Fully Developed*** ***Operational***

NASA Case Number: ARC-14785

4. ASSESSMENT OF USE.

a. *If the contribution is now in operation, describe its performance and value within both the aerospace field and its application to non-aerospace commercial and government uses.*

CIP's performance has been excellent throughout the MER mission. Since it became operational in mid December 2003, CIP has been running 24 hours/day. It has been non-operational less than five hours, for an up–time of better around 99.8%. As shown in the statistics section of this document, CIP has delivered over 100GB of file data to users. At JPL, the mission control and science assessment areas have continuously maintained CIP clocks and schedules during this entire time.

According to testimonials from the mission staff, the key values that CIP provides them include:

- Time savings.
- A quick and easy way to retrieve any pertinent documents or data products.
- Situational awareness or the time management aspect of correlating time, events, and staffing.
- Answers to questions
  - What's going on?
  - What do I need to do?
  - How long do I have to do it?
  - Who's on staff and in what roles?
  - What time is it?
  - What time will it be?

- When will the next communications passes occur?
- Where are we in each rover's daily timeline?

The robustness of the rovers and the good weather on Mars has convinced NASA to extend the MER mission. However, many mission personnel are now working at their home institutions. They will have a greater need for the ability to access mission schedules and data from outside the flightops firewall. CIP will provide this access.

Projects at NASA and other agencies such as the FBI will become more complicated as technology improves and goals expand. This complexity increases the need for people to work collaboratively in a heterogeneous and distributed project environment.

As interplanetary communications bandwidth improves and scientific software becomes more productive, data sets will grow exponentially. All time critical missions need scheduling and data management tools. CIP enhances productivity by integrating all of its tools into a coherent package.

As complexity grows, it will be more and more difficult to shoehorn users into a few rigid applications. Software and systems will need to be more adaptive to the computing environment and user needs. CIP adapts by automating data acquisition and schedule correlation. Its middleware services are dynamically reconfigurable. These aspects of CIP are useful in both commercial and government applications.

b. If the contribution is not now in operational use, describe its most likely or previous applications and the extent of commercial,(includes non-aerospace commercialization) government and/or NASA-specific uses.

N/A: CIP is currently in operational use on the Mars Exploration Rovers Mission.

c. Will the contribution increase in value or in its applications over time and in what manner?

CIP's contribution to NASA will increase over time. For future missions, NASA will apply both CIP itself, as it evolves from its original incarnation for the MER mission, and the design principles that CIP used and validated.

CIP will continue to evolve and adapt itself to future missions. These missions can plug in new middleware services and replace or remove unneeded services. Different client applications can use the web services interface to communicate with the middleware services. The new or updated middleware services will access future forms of data repositories.

CIP validated several key design principles that future NASA software products can use:

Platform independence. CIP is completely based on the Java programming language, and so its client applications, middleware, and back end utilities run on different machine platforms and operating systems. Users are less and less willing to tolerate platform restrictions.

Component–based software architecture. Well–designed components such as the ones in CIP are easier and faster to develop and debug. Code sharing and reuse are much more possible with components.

Commercial off–the–shelf software. As software systems become larger and more complex, it becomes harder and harder to complete projects on time. Not reinventing wheels and purchasing commercial off–the–self software, especially infrastructure or key tools and utilities, saves time and resources. CIP used the Java platform and BEA's WebLogic application server.

Industry standards. As software systems become larger and more complex, successful integration becomes increasingly critical. Following industry standards makes successful integration possible. J2EE was a key standard that CIP followed.

Three–tier enterprise architecture. As systems become more global, partitioning applications into client, middleware, and back end (data repository) tiers connected across the network will distribute and balance computational resources.

Service–oriented middleware. The CIP middleware is a collection of services that respond to client requests. This is a very simple model for future projects. Services that are independent of each other make it possible to plug in new services and update or remove old ones, so the middleware can evolve and adapt.

Web services. Web services are a widely accepted industry standard that is language and platform independent. Rewrap legacy software as web services to make the software accessible on the Web and to give it a future on the Internet.

5. CREATIVITY.

What is your assessment of the creativity displayed in the conduct of this contribution, relative to the expected performance of those in similar positions?

*None*________*Low* __________*Modest*_________*Average*________*High*_________*Very High*______X____

6. RECOGNITION

What forms of recognition have been received by the contributors for this contribution? Have previous awards been made to the contributor(s) for this accomplishment? Please describe.

Awards:

- *Ames Honor Award* for Excellence in the Category of Group/Team, Code I MER Technology Infusion Team, September 25, 2003
- *USRA/RIACS Performance Award* for successful design, deployment, and utilization of CIP during the MER mission, Ron Mak, March 2004

Presentations:

- *"The CIP Middleware Architecture"* and *"InfoStructure: A Java–Based Distributed System for Analysis and Collaboration"* presented at SAE 2002 World Aviation Congress and Display, November 2002, Phoenix, AZ.
- *"Darwin, Web Services, and Mars: The Collaborative Information Portal"* presented at JavaOne 2003, June 2003, San Francisco, CA.
- *"NASA's Mars Exploration Rovers and The Collaborative Information Portal"* presented to the San Francisco Bay Area Chapter ACM, November 2003, Cupertino, CA.
- *"NASA's Collaborative Information Portal: HCI Lessons Learned"* seminar presented to the Stanford University Program in Human–Computer Interaction, February 2004, Stanford, CA. See http://hci.stanford.edu/seminar/abstracts/03-04/040227-mak.html
- Keynote address (not yet titled) to be given at the BEA eWorld Conference, May 2004, San Francisco, CA. See http://www.bea.com/eworld/agenda/keynote_speakers.htm
- "*Java, Web Services, and Mars: A NASA Trip Report*" to be presented at JavaOne 2004, June 2004, San Francisco, CA.

Papers:

- *"Collaborative Information Portal: MER and Beyond"* paper published in the Proceedings of the First International Space Mission Challenges for Information Technology (SMC–IT 2003), JPL Publication 03–13A, July 2003, Pasadena, CA. Available at http://webdev5.jpl.nasa.gov/eventmanager/uploads/smc_it/SMCIT03JWaltonMS.doc

7. TANGIBLE VALUE.

As a measure of the tangible value of this contribution, estimate the following:

a. *NASA cost savings* to date and in future years.*

Cost savings during nominal mission operations: $1,142, 400.00.
Cost savings during extended mission operations: $1,611,600.00.

Savings = 1 hour per day x _ complement @ $85.00 per hour x duration
Where _ complement = 120; nominal mission duration = 112 days, extended mission duration = 158 days

**State the rationale for the above cost estimates.*

b. *Current market value and potential as a commercial product or process.*

CMV based upon development investment = $12M
Cost to implement on an identical mission = $300K
Cost to implement on an identical mission on a per user basis (on a MER scale) = $860.00
Cost to implement on a different mission = $2M

c. Other measurable value: increased efficiency, enabling technology, improved management, etc.

Dr. Jeffrey R. Johnson, MER Science Team Member, U.S. Geological Survey

“In short, the CIP software package and its developers provided one of the most useful tools available to the MER project and supported its usage at a professional level. Without CIP’s availability during the MER mission, the ability of the MER team to perform its duties in an efficient manner would have been compromised greatly.”

*****

Dr. Joy Crisp, MER Project Scientist, JPL

“There was no other ‘one-stop-shopping’ and common interface for all these different schedules.”

“It’s no major breakthrough, but I've needed to know something, and usually I need to know it quickly and so it has just come in handy in little ways that add up to an important tool. Without it I would have been stuck, taking a lot more time, sometimes I don’t have that time. So I would have missed a meeting or not been able to find out when somebody was going to be on their job. So it’s just kind of a little helper in the background that's very important.”

“Some features on CIP can’t get elsewhere, like looking for new files.”

“I was amazed how … it really just seemed like a customer tool. Although I think you guys tried to minimize your impact to the team of course to make a tool better you need to keep finding out what do you want, what do you need, what do you want changed. And somehow you did that with what seemed to me very minimal impact to the teams. I don't know how you did it. Its very hard to on short notice put together a tool that is so useful and adapt to the changes that were happening in the project as we were going along. We were changing the OSS, we were doing things. And every now and again we would ask you. Like I remember MER science was an area we wanted to be able to search on and you made that happen. That was very important. So responding to our requests and somehow coming up with a tool that was way more useful than it was in the beginning (laugh) that meant you designed it in a direction that was the direction the customer needed rather than what you thought the customer needed. So bravo.”

*****

Ron Li, Ohio State University

“Much of the work has been carried out at the home institution, the Ohio State University, which requires that information such as schedules, reports and image data be received, so that the mapping products and rover positions can be computed and delivered in a timely way. CIP has been working effectively and supported our mapping and localization efforts greatly.”

*****

Dr. John L. Callas, MER Science Manager, JPL

“CIP became the de facto schedule for the team, due to its sophistication, stability, ease of use, and compatibility with a variety of computer platforms. People learned when and where they should report each day and what’s going on at any given moment on either rover with CIP. It would have been extremely difficult to conduct our challenging rover operations without it.”

*****

Laurence A. Soderblom, U.S. Geological Survey

"In my capacity on the mission I have found the CIP software system indispensable. During more than 30 years of experience in NASA planetary flight missions, I have seen nothing that even remotely competes with CIP in value to the science operations."

*****

Jessica A. Collisson, Flight Director, MER Project

"As a member of the Mars Exploration Rover (MER) Project Operations Team, I can attest to how much the tactical operation of the rover relies on the different capabilities of this tool … being the medium for communication of spacecraft and support personnel activities. Not only does CIP provide a means to communicate with the team a clear, concise, and multi time zone format, of rover communication sessions and other spacecraft critical activities, it also supports the scheduling of personnel activities in order to keep the spacecraft activity planning process flowing in a timely manner."

*****

Jim Erickson, Mission Manager for MER project

"We are one of the places were CIP is in use, in fact I think it's actually the only place right now, I expect it will be used on other missions from now on."

"In addition, we talked about knowing when the uplinks are going to happen and when the downlinks are going to happen, and knowing among other things when I have to go up to a science team meeting and give them answers on how the vehicle is doing. So the scheduling portion of CIP is also of some interest to me. In fact, it turned out to be about the only way I could keep track of where the meetings are that I had to go to."

"But the biggest thing that was the 'aha' thought was probably when my family wanted to know when I was going to be working and when I was going to be home."

"I was substantially pleased by the product that was delivered. In a lot of ways. One, it was more tailored to what we need to do than I was expecting. That leads into the other comment that I wanted to make that is that the team did a great job in listening to what we are saying and finding out things that would help us along the way iterating their product to come up with something that was very useful. Like I said, everything it does you could do theoretically another way at much more time and effort. And that would mean that there are things elsewhere that we could do. So I was very pleased with the response from the team, both in getting the initial products out, tailoring it to what we are doing, adapting to what was good and bad about the original products and doing the build a little, test a little, fix a little scenario in a way that helped MER."

*****

Andy Mishkin, MOS Development Mgr MER, Deputy Sequencing Team Chief, Tactical Uplink Lead

"I pretty much use it constantly. I primarily rely on the use of the schedule that's shown here, to see where we are. In particular, when we are working Mars time, to know what our deadlines are coming up, to know how much time we have left and what time it is."

"I've also had some cases when I was trying to pull over for the first time some information, and I didn't have an available workstation when the sequencing area was crowded. I was able to pull over our initial sequence summary and start working on how everything was going to be planned out for the sol without having to tie up another workstation. It made my laptop suddenly usable. So there have been cases like that.

But mostly it's just integrated into what we do everyday."

*****

Steve Spohn, MER Mission Data Operations team chief

"CIP is a highly regarded tool, and it's a visual tool that everybody uses. It's up on our main screens all the time in the MSA. It is the one ubiquitous tool that everybody looks to find out when things are happening on the project. So it's clearly an asset for this mission."

*****

Mike Wolfe, participating scientist on MER science team

"I do use CIP, I use it often. I must admit the most recently I've been using CIP for the clocks. We love the clocks. "

"It's extremely helpful when you're offsite. So you've got your VPN and you get into CIP, it's very good to be able to track things because when you're offsite you're definitely on Earth time, so you quickly lose touch with the Mars times."

*****

Eric Wood, power team, software engineer who also does daily downlink operations

"I find it really useful to help me understand where we are in the process. Specifically understanding the schedules and when the downlinks are going to happen."

*****

Craig Leff, science downlink coordinator

"I do. It's probably my favorite tool that I use in the mission. I use it from the time I come in through the end of the day. In fact, use it a home to monitor what is going on."

"A couple of times people have asked do you know the answer to this is, and very quickly go into CIP and pull up the answer I need."

"Now that I see it, I would argue that it is the most useful software tool that I have used. Certainly one that's custom for MER ... almost everything I need, one stop shopping … CIP probably for day in and day out for getting my job done is probably as I said is probably the most number one helpful tool that I've had."

*****

Bryan Allen, MER MDOT team

"Two MERBoards behind the mission manager area and those have been pretty much through the whole project exclusively just to display local solar time for the two spacecraft, and then typically the other two favorites are UTC time, which is what all the timestamps on the data are, and then the local time here in Pasadena."

*****

Diana Blaney, HS investigation scientist, Mini-TES DL, science theme group

"I use CIP a lot. When I come in on shift I use it to keep track of when all the different meetings are, and when they come up. I use CIP at home to figure out when I need to be at places, and I use CIP to calculate in advance what my schedule is. I knew what Sols I was working, but they didn't have the start time of the shift."

APPLICANT'S SIGNATURE: ____DATE:_____________

NASA Case Number: __________ **3**

SECTION II COMMENTS AND CONCURRENCE

1. EVALUATOR

I recommend/do not recommend a Space Act Award for this contribution for the following reasons.

Printed Name and Signature	*Title*	*Date*
NASA Installation	*Contractor*	*Other*

2. EVALUATOR'S SUPERVISOR

I support/do not support a Space Act Award for this contribution for the following reasons.

Printed Name and Signature	*Title*	*Date*

3. TECHNICAL MANAGEMENT (required signature)

I support/do not support a Space Act Award for this contribution for the following reasons. Further, I verify that the contribution is significant to NASA Aeronautics and space Activities and that NASA has adopted, supported, sponsored or used this scientific or technical contribution.

Printed Name and Signature	*Title*	*Date*

4. TECHNOLOGY TRANSFER MANAGEMENT

I support/do not support a Space Act Award for this contribution for the following reasons.

Printed Name and Signature	*Title*	*Date*

TO BE COMPLETED BY AWARDS LIAISON OFFICE

5. IDENTIFICATION OF CONTRIBUTORS

Contributor Name	*Employer*	*Percentage of Contribution*
Joan D. Walton	NASA/Ames	14
Leslie Keely	NASA/Ames	12
Sandra Johan	NASA/Ames	12
Ronald Mak	UARC	12
John Schreiner	NASA/Ames	5
Louise Chan	SAIC	5

Tarang Patel	SAIC	5
Quit Nguyen	SAIC	5
Robert Filman	RIACS	5
Elias Sinderson	CSC	5
Matthew D'Ortenzio	NASA/Ames	5
Vish Magapu	SAIC	5
Kim Hubbard	NASA/Ames	5
Dennis Heher	SAIC	5

NASA Case Number ARC-14785 *4*

—

6. PATENT INFORMATION

Patent Applied for? Y/N Granted? Y/N Y Filed	*Serial Number or Patent Number*
Application filed by: Government? Non-Government? Government	*Date Filed or Granted*
License Granted Y/N	*Company Name:*

7. EVALUATION NUMBER 1 2 3

8. BUSINESS ADDRESS OF CONTRIBUTORS IF OTHER THAN NASA EMPLOYEES

SAIC
UARC
CSC

9. AWARD LIAISON OFFICER COMMENTS AND SIGNATURE (required)

Printed Name and Signature	*Comments*	*Date*

General Statistics

Registered Users = 330
Over 475 clients installed
Average number of active users at any given time = 52
Total download stats for mercip2 as of March 29, 2004 = 234.3 K files, 68.5 GB
Total download stats for mercip4 as of March 29, 2004 = 45.0 K files, 32.0 GB
Total server downtime since mission start = 4 hours

CIP Preferences Files Analysis

Files collected on March 27, 2004 from mercip2

General File Information

Total files = 258

Number of files modified within the last week = 88
Number of files modified within the last two weeks = 123
Number of files unmodified since January 4, 2004 = 13

Maximum file size = 57502 bytes
Minimum file size = 1737 bytes
Files with size > 40K = 6
Files with size > 30K = 60
Files with size < 10K = 67

Current Tab Frequencies

The current tab indicates which tool was being used when the user last saved.

ScheduleViewer = 204
BrowseFiles = 30
TimeConverter = 20
Overview = 6
NewFiles = 3
Observations = 1

Layout Configuration Frequencies

Default = 255
ScheduleViewer = 14
Clocks = 8
DataNav = 5
OSSBrowser = 1

Clock Timezone Frequencies

America/Los_Angeles = 243
LST-A = 181
LST-B = 170
UTC = 88
SCET = 16
America/Anchorage = 12

```
America/New York = 5
ERT = 4
Europe/Copenhagen = 3
America/Chicago = 2
Europe/Berlin = 2
Asia/Tokyo = 1
Australia/Canberra = 1
Europe/Madrid = 1
Europe/Moscow = 1
PORT Timezones = 12
```

Clock Format Frequencies

```
Month Day Year = 698
DOY = 18
Year DOY = 9
Year-DOY = 4
Yyyy-MM-dd = 1
```

Clock Count

```
Users with 3 clocks = 80
Users with 4 clocks = 46
Users with 2 clocks = 22
Users with 5 clocks = 10
Users with 1 clock = 2
```

Top Schedule Frequencies

```
MER-A Tactical Timeline = 203
MER-A Comm Events = 146
MER-B Tactical Timeline = 139
MER-B Comm Events = 120
MER-A Science Team Staff = 58
MER-B Science Team Staff = 58
MER-A PIO Events = 41
MER-B PIO Events = 20
CIP Support Staff = 20
MER-A SMSA Events = 16
MER-A Activity Plan = 16
MER-B Activity Plan = 16
MER-A MIPL Staff = 12
MER-B MIPL Staff = 7
Custom Schedules = 326
```

Schedule Count

```
Users with at least one schedule = 246
Users with at least 3 schedules = 184
Users with at least 5 schedules = 105
Users with at least 10 schedules = 20
Users with 30 schedules = 1

Total schedules = 1198
Average number of schedules = 5
```

Schedule View Option Frequencies

TimeSpanBeingDisplayed

The TimeSpanBeingDisplayed indicates the amount of time being displayed (in milliseconds) in the schedule viewer Gantt chart.

- Users with a 4 Week (2419200000 ms) time span = 0
- Users with a 3 Week (259200000 ms) time span = 4
- Users with a 2 Week (120960000 ms) time span = 0
- Users with a 1 Week (604800000 ms) time span = 3
- Users with a 3 Day (259200000 ms) time span = 0
- Users with a 2 Day (172800000 ms) time span = 16
- Users with a 1 Day (86400000 ms) time span = 210
- Users with a 12 Hours (43200000 ms) time span = 17
- Users with a 6 Hours (21600000 ms) time span = 1

lineHeight

The lineHeight specifies the line height in pixels for the rows in schedule viewer.

- Users with “Short” (18 pixel high) rows = 63
- Users with “Standard” (24 pixel high) rows = 13
- Users with “Tall” (32 pixel high) rows = 173

timescaleCount

The timescaleCount indicates how many time scales the user has displayed over the Gantt chart.

- Users with 1 timescale = 95
- Users with 2 timescales = 62
- Users with 3 timescales = 78
- Users with 4 timescales = 16

Timescale’s time zone

- Users displaying a America/Los_Angeles time zone timescale = 241
- Users displaying a LST-A time zone timescale = 128
- Users displaying a LST-B time zone timescale = 112
- Users displaying a UTC time zone timescale = 32
- Users displaying a SCET time zone timescale = 2
- Users displaying a America/New York time zone timescale = 1

ShowNowBar

- Users displaying the now bar (True) = 251
- Users not displaying the now bar (False) = 0

ShowBarLabels

- Users displaying bar labels in the Gantt chart (True) = 249
- Users not displaying bar labels in the Gantt chart (False) = 2

Event Horizon Timezone Frequencies

America/Los_Angeles = 177
LST-A = 35
LST-B = 34
UTC = 10

Event Horizon Refresh Option Frequencies

Update events by name = 26
Show all meetings = 21
Delete all events = 1
Do nothing = 1

OSSBrowser Top Directory Frequencies

```
The top directory indicates the top directory shortcut selected in OSSBrowser at the
last save.

MERA-Sol = 31
MER-Strategic = 24
MERB-Sol = 23
MERA-Tactical = 11
MERB-Tactical = 8
MERSCI = 4
MERA-surface = 3
MERB-surface = 2
MERA-Strategic = 1
MERB-Strategic = 1
```

BAT Message Frequencies

Surface Ops Metrics for 1/4/2004 to 3/29/2004

Number of high priority messages:	12
Number of normal priority messages:	94
Total number of messages:	106
Number of surface ops days:	86
Average number of messages per day:	1.232558
Number of surface ops message senders:	27
Average number of messages per sender:	3.9

Message counts by mission:

MER Messages

Number of CIP messages:	13
Number of data product messages:	8
Number of miscellaneous messages:	3
Number of OWLT messages:	1
Number of schedule change messages:	1
Grand Total of MER messages:	26

MER-A Messages

Number of atmospheric related messages:	6
Number of data product messages:	40
Number of miscellaneous messages:	2
Number of usage error (blank/partial) messages:	2
Grand Total of MER-A messages	50

MER-B Messages

Number of data product messages:	25
Number of miscellaneous messages:	4
Number of schedule change messages:	1
Grand Total of MER-B messages	30

Metadata and Streamer Log File Analysis

Files collected on March 29, 2004 from mercip2

Metadata Query Frequencies (February 18, 2004 to March 29, 2004)

Total user queries (not including cached queries) = 12558
Average of 6 queries per user per sol.

Maximum result size = 743784 records
Minimum result size = 0 records
Number of results > 5000 records = 5
Number of results > 1000 records = 40
Number of results > 100 records = 440

Number of selects for MER-A = 6933
Number of selects for MER-B = 4600
Number of selects for MER-T = 242

Data products = 10491
Reports = 1154
Plans = 278

OPGS = 6173
SOAS = 300
APSS = 85
SSW = 113

APXS = 1131
EDL Cam = 158
Front Hazcam = 640
JPEG = 632
Microscopic Imager = 753
Mini-TES = 251
Moessbauer = 370
Mult = 6
Navcam = 594
Pancam = 1212
RAT = 137
Rear Hazcam = 468

Streamer Query Frequencies (February 24, 2004 to March 29, 2004)

FileInfo = 18947
Average of 9 queries per user per day.
Preferences downloads and uploads = 3950

Streamer Service Downloads (February 24, 2004 to March 29, 2004)

Total downloads = 39099
Average of 19 downloads per user per day.

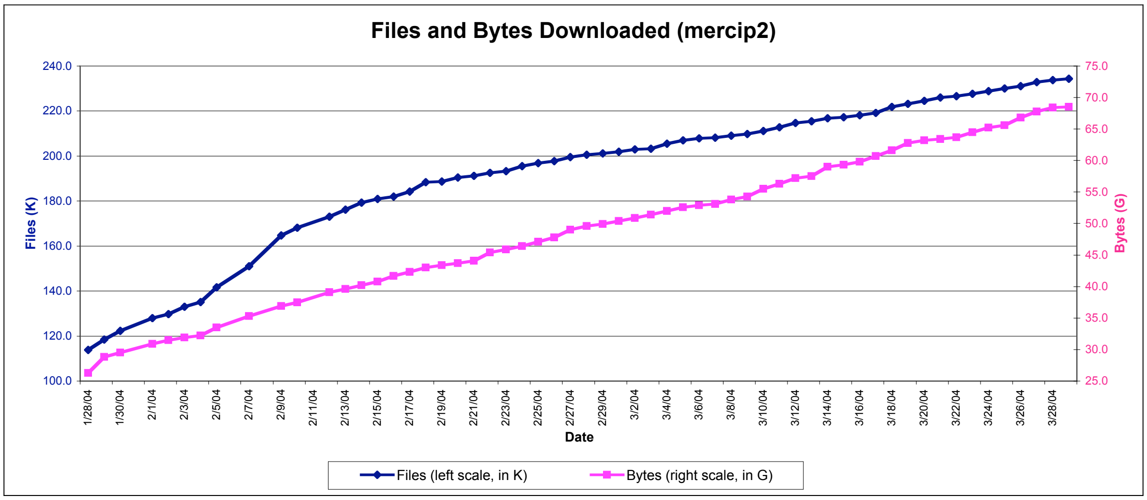
MER-A = 15393
MER-B = 15814
Strategic = 49

OPGS = 24967
SOAS = 3632
SSW = 233
APSS = 780

```
APXS = 36
EDL Cam = 9
Front Hazcam = 666
JPEG = 6339
Microscopic Imager = 2784
Mini-TES = 134
Moessbauer = 95
Navcam = 1566
Pancam = 16748
Mult =  0
RAT = 0
```

Downloads From Start of Mission to March 29, 2004

```
Total files downloaded = 234300
Total GB downloaded = 68.5
```



Loader Log File Analysis

Loader Frequencies (January 2, 2004 to March 28, 2004)

```
Logical records inserted for MER-A = 890319, physical records = 6232233
Logical records inserted for MER-B = 703028, physical records = 4921196
Logical records deleted for MER-A = 94001, physical records =  658007
Logical records deleted for MER-B = 88748, physical records = 621236
Logical records updated for MER-A = 526261, physical records = 526261
Logical records updated for MER-B = 360397, physical records = 360397

Total NFSLogd operations processed = 3769241 events*
```

*Includes write, rename, remove, mkdir, rmdir, symlink, and link, and excludes read, create, and setattr.

Notes: Many of the NFSLogd operations are filtered out and not processed. A logical record corresponds to a single file on OSS, however physical insertions and deletions into the database require 7 operations per file.

Schedule Log File Analysis

Schedule retrievals by CIP client users:

	Cumulative Totals	Monthly Totals January	February
Number of people who retrieved schedules:		231	225
Number of schedule retrievals:	60632	32239	28393
Number of Event Schedule retrievals:	45405	23293	22112
Number of Team Schedule retrievals:	11719	6369	5350
Number of Personnel Schedule retrievals:	2553	1810	743
Number of Role Schedule retrievals:	955	767	188
Subtotal retrieval by type:	60632	32239	28393
Number of schedule metadata retrievals:	6708	5192	1516

Schedule uploads and downloads by schedulers:

	Cumulative Totals	Monthly Totals January	February
Number of schedulers modifying schedules:		25	20
Number of schedule uploads*:	654	336	318
Number of workbook uploads:	374	202	172
Number of schedule downloads:	50	40	10
Number of workbook downloads:	270	161	109

* Schedule uploads correspond to requests to the schedule load manager, a.k.a. Schedule Interpreter, to load the schedule data into the schedule schema (POISE).

Oracle Database Average Work Load

Data collected from 3/18/2004 to 3/30/2004.

Number of executes = 10.16 /sec
Number of queries generated = 15.29 / sec
Number of Reads = 4727.78 /sec
Number of Writes to disk = 5.01 /sec
Number of disk blocks modified = 17.74 /sec